CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

INCLUDING PRESTRESSED CONCRETE

JULY, 1953. **Vol. XLVIII, No. 7**

FORTY-EIGHTH YEAR OF PUBLICATION

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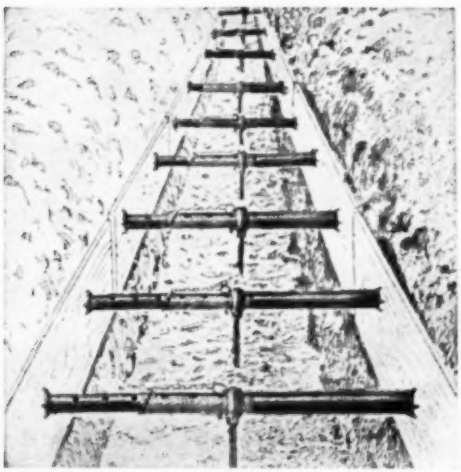

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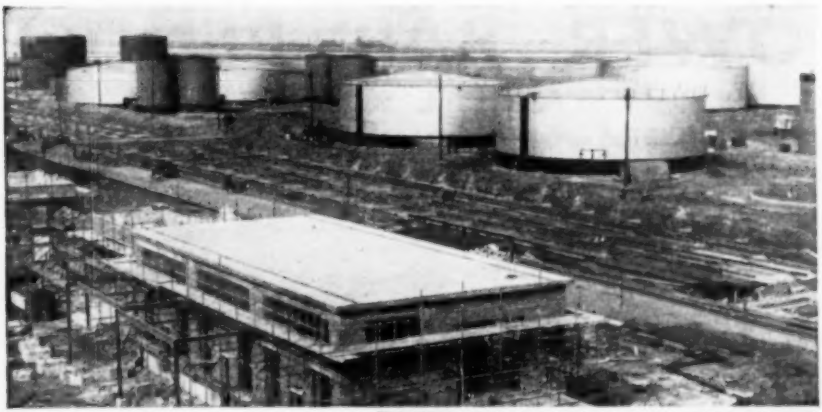

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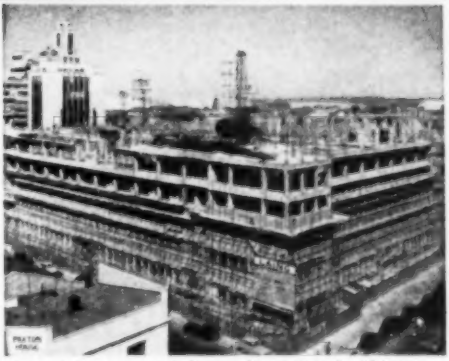

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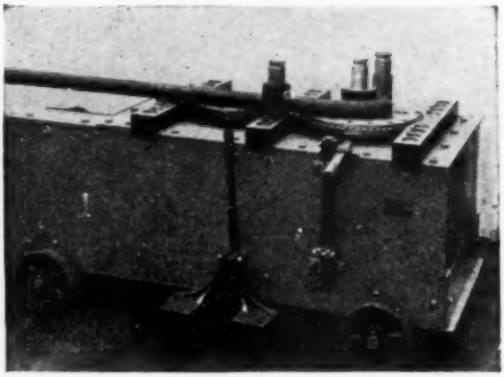

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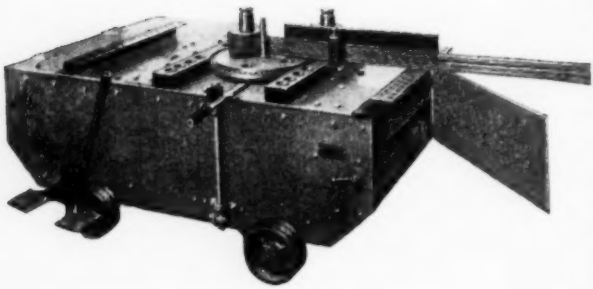

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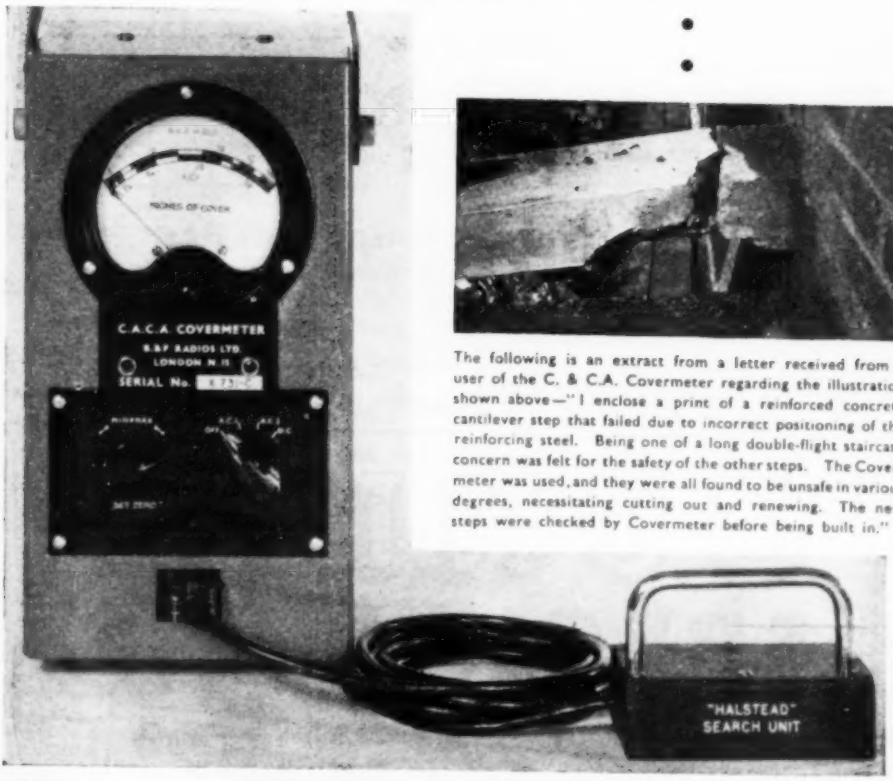

The following is an extract from a letter received from a user of the C. & C.A. Covermeter regarding the illustration shown above—"I enclose a print of a reinforced concrete cantilever step that failed due to incorrect positioning of the reinforcing steel. Being one of a long double-flight staircase concern was felt for the safety of the other steps. The Covermeter was used, and they were all found to be unsafe in various degrees, necessitating cutting out and renewing. The new steps were checked by Covermeter before being built in."

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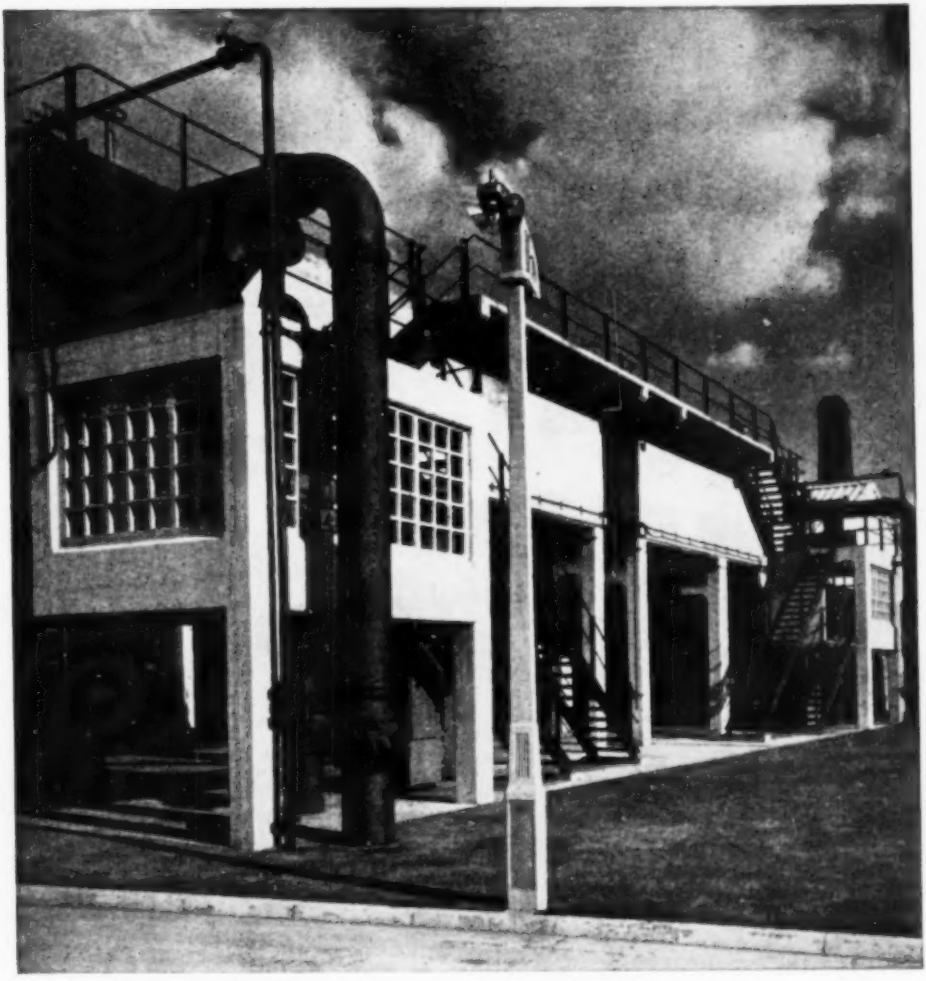

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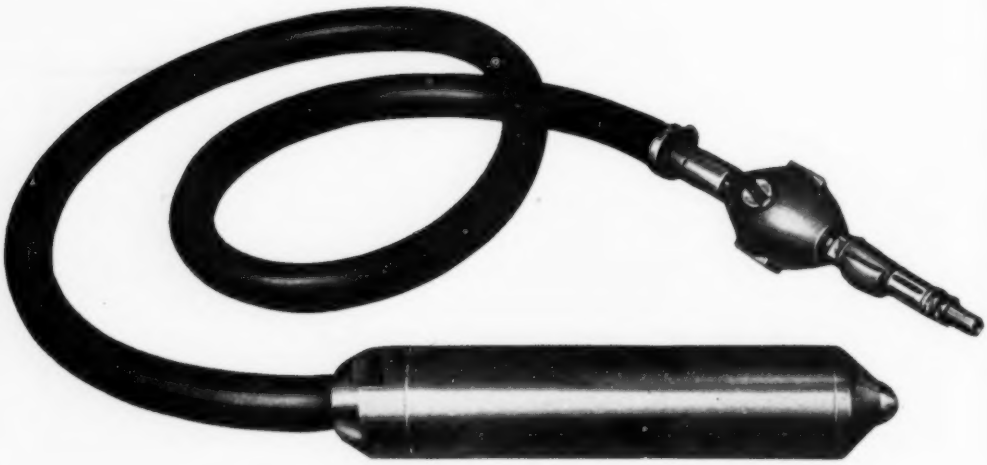

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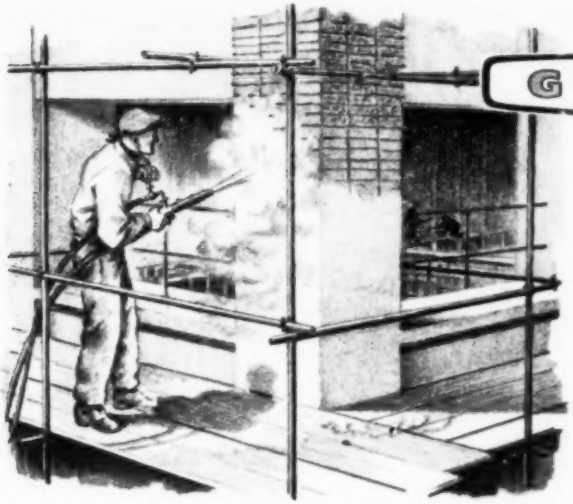

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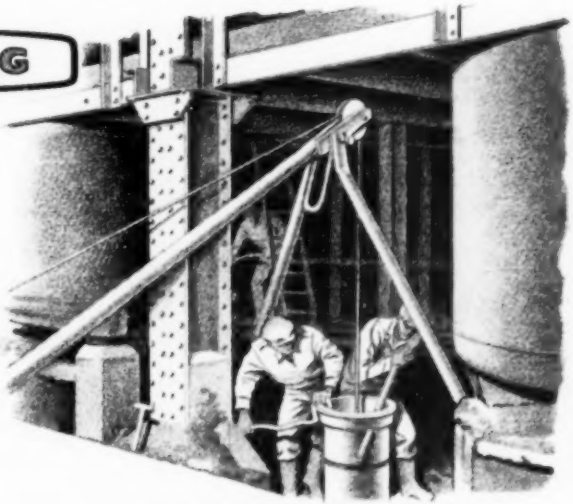

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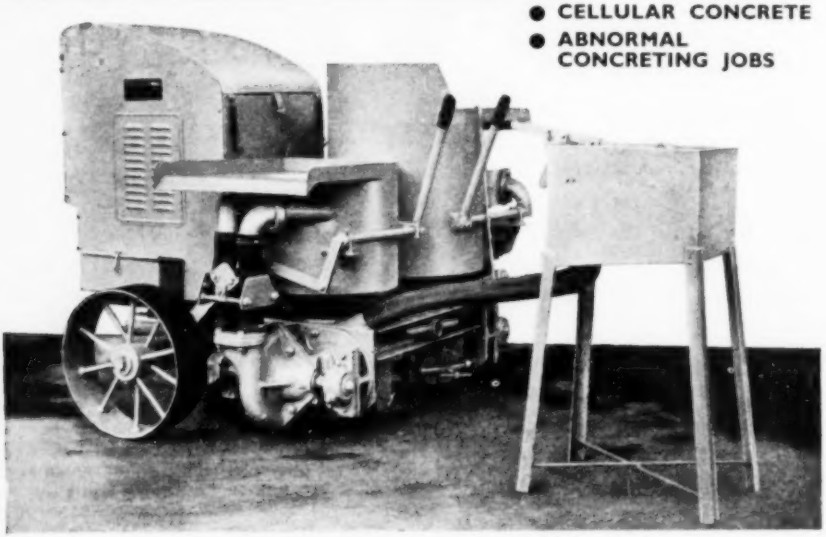

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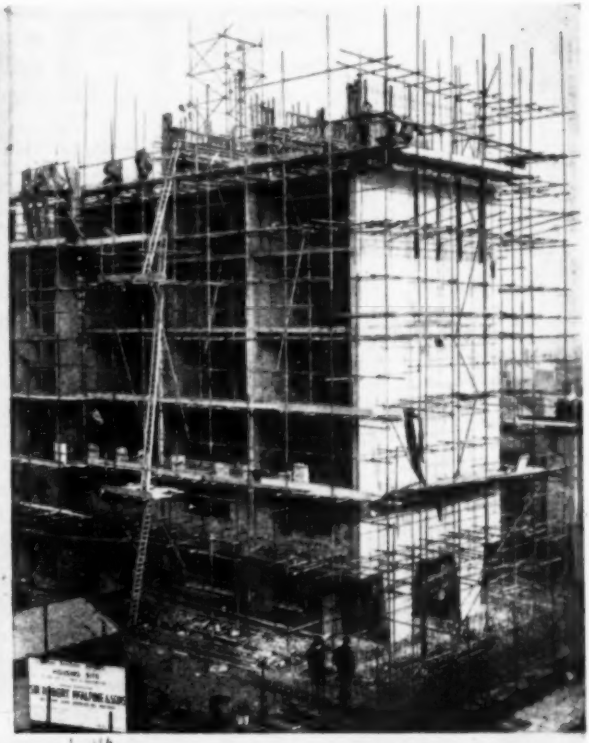

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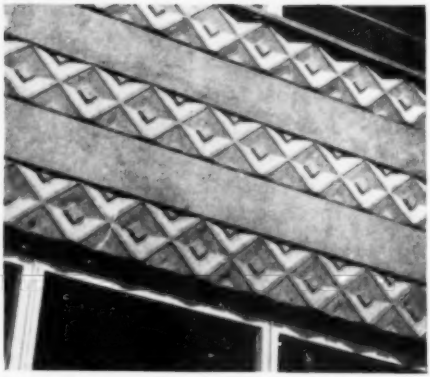

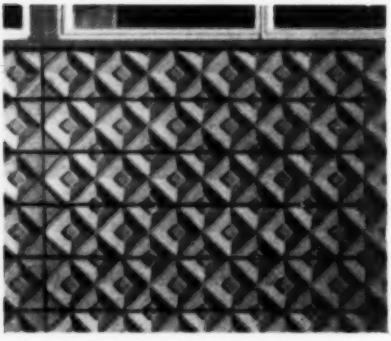

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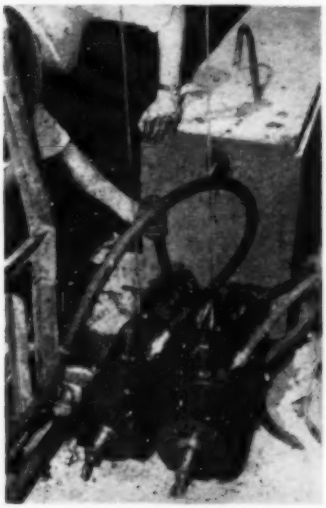

Engineer to the Lee Conservancy Catchment Board : M. Nixon, M.B.E., B.Sc., A.M.Inst.C.E. Prestressed concrete beams made by Shockcrete Products Ltd. for the main contractors, Concrete Piling Ltd.

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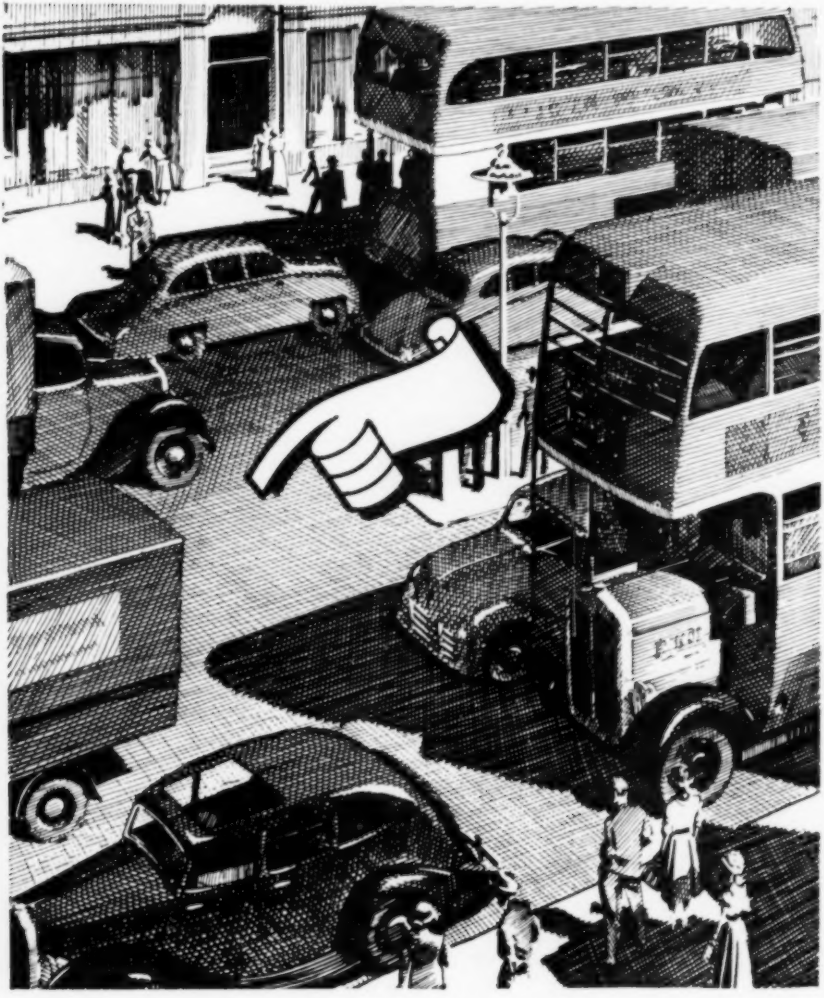

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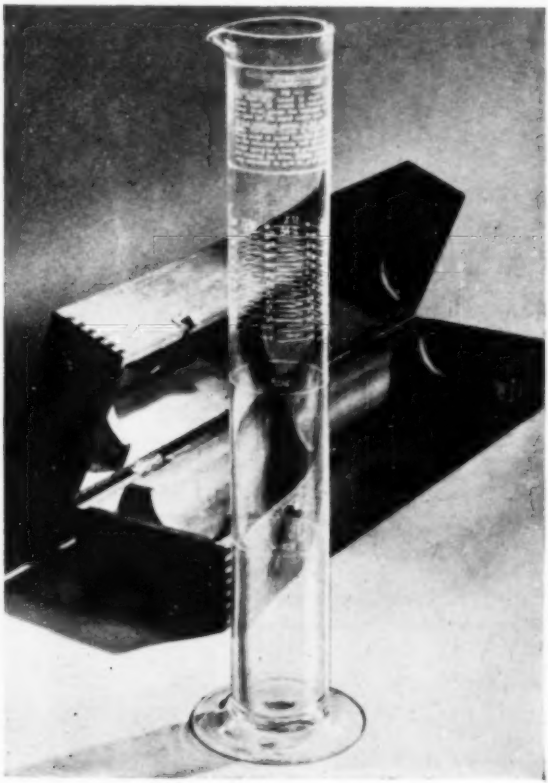

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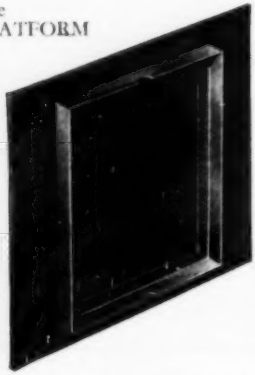

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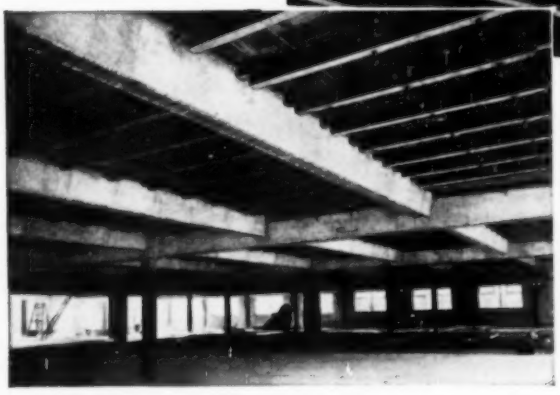

The above illustration shows Flatforms being laid in position.

Illustration left shows Spanforms and decking supported on concrete haunching.

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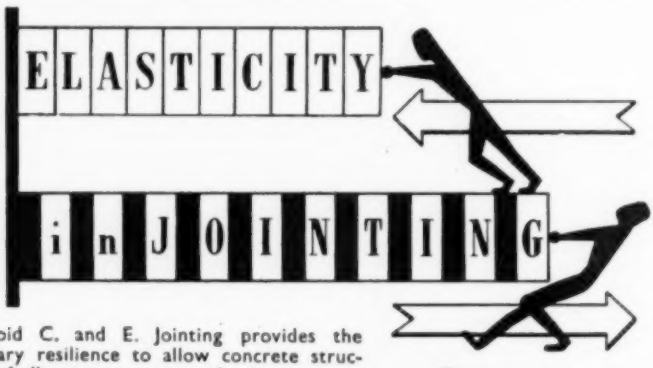

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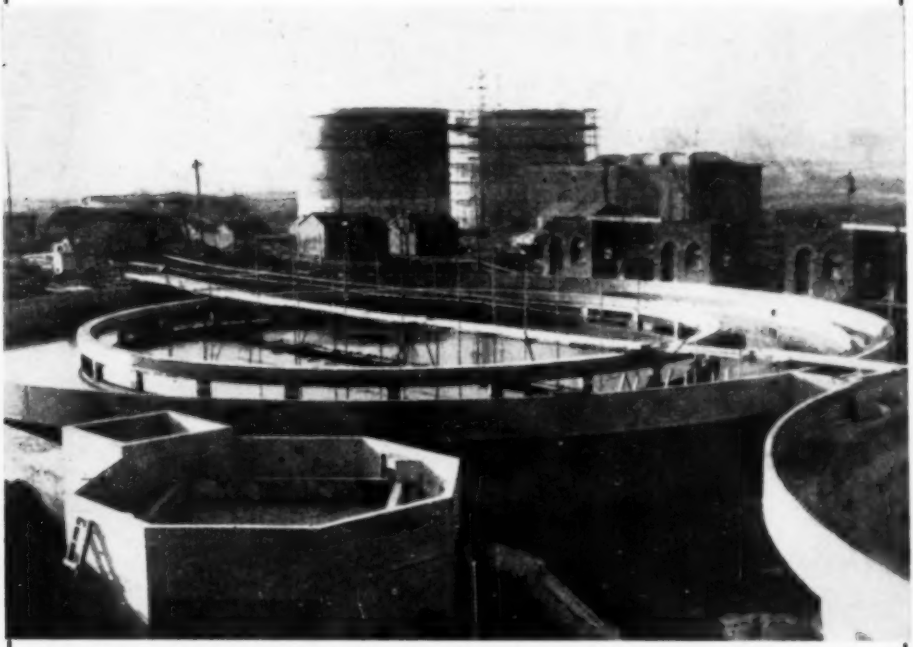

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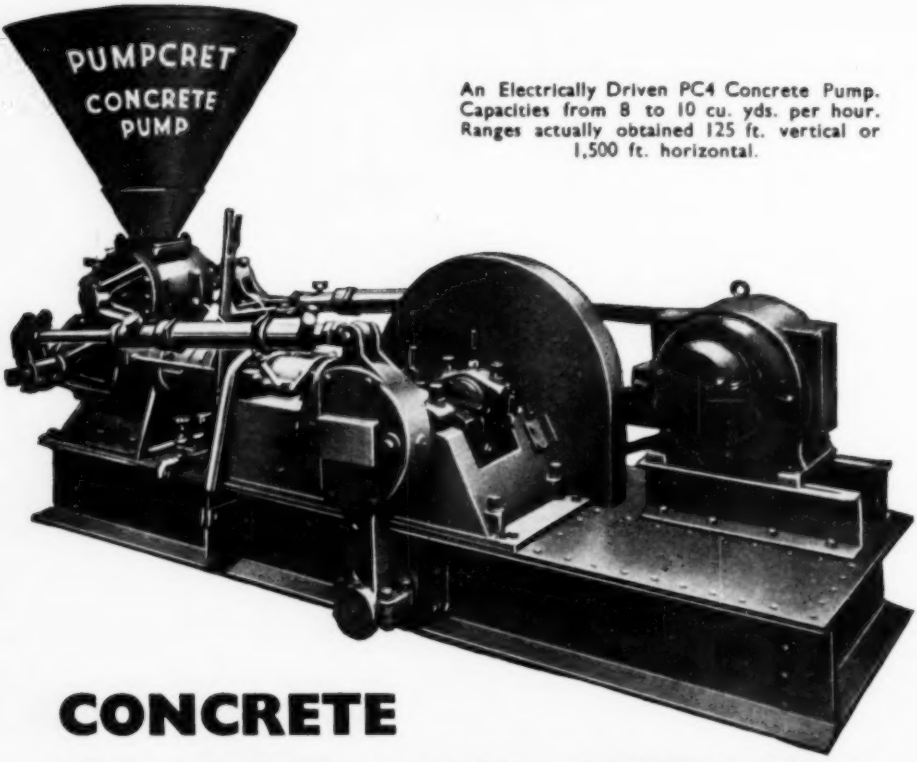

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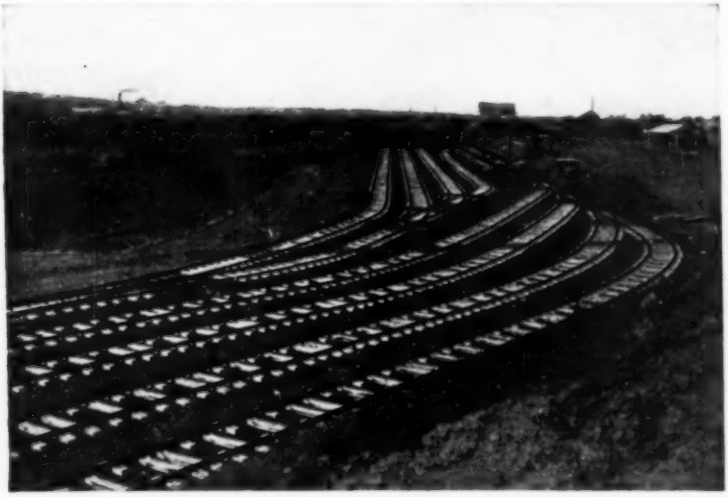

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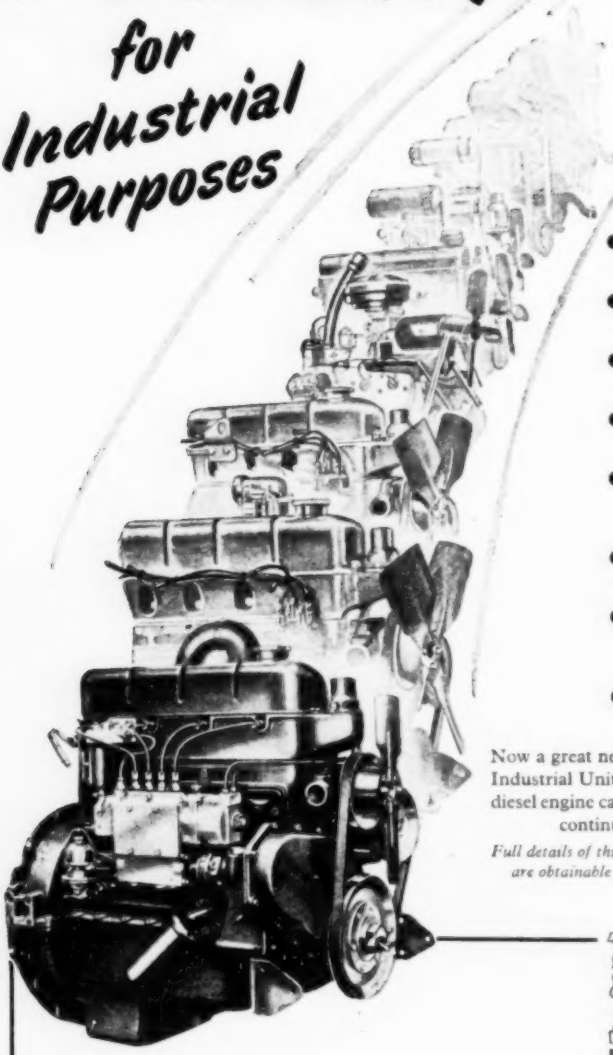

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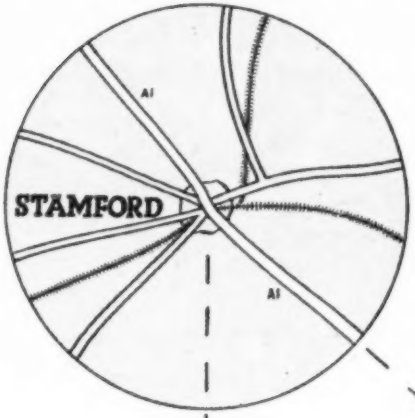

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Prestressed concrete beams in use on the partly-completed road-over-rail bridge on the Great North Road at Stamford. This illustration shows one of several trunk road bridges at present under construction using "ANGLIAN" prestressed beams.

Photograph by courtesy of British Railways, Eastern Region. Contractors: Messrs. Wellerman Bros. Ltd., Sheffield

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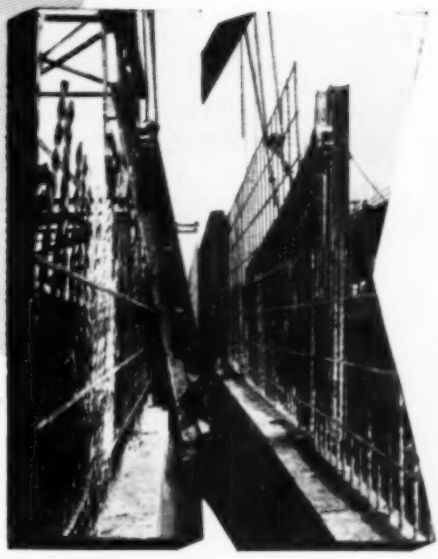

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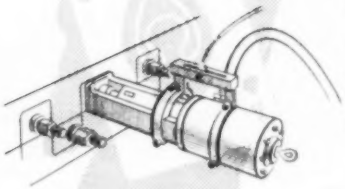

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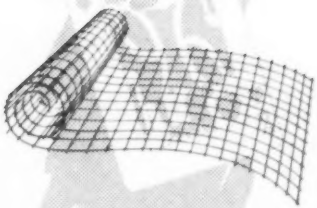

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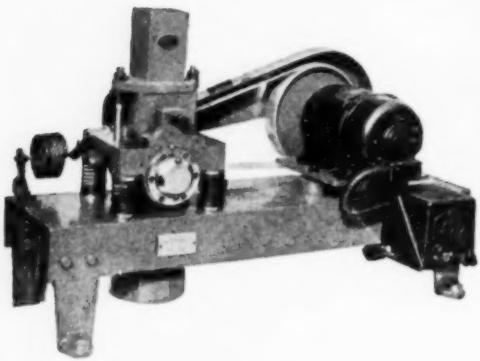

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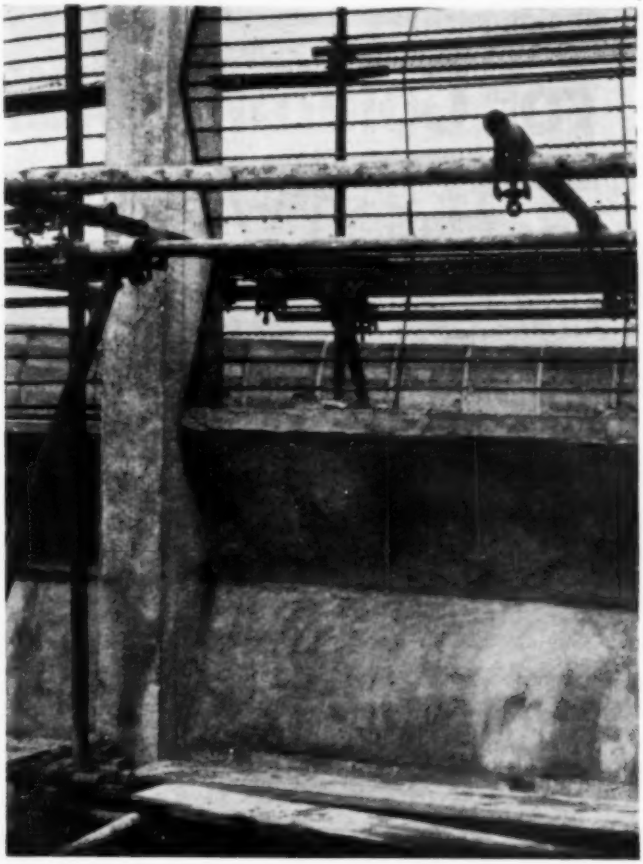

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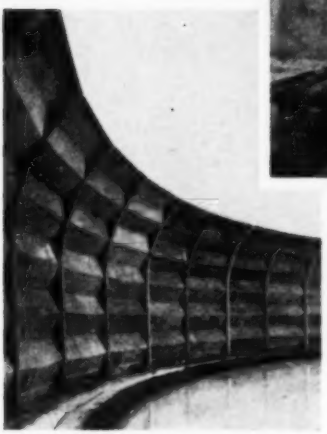

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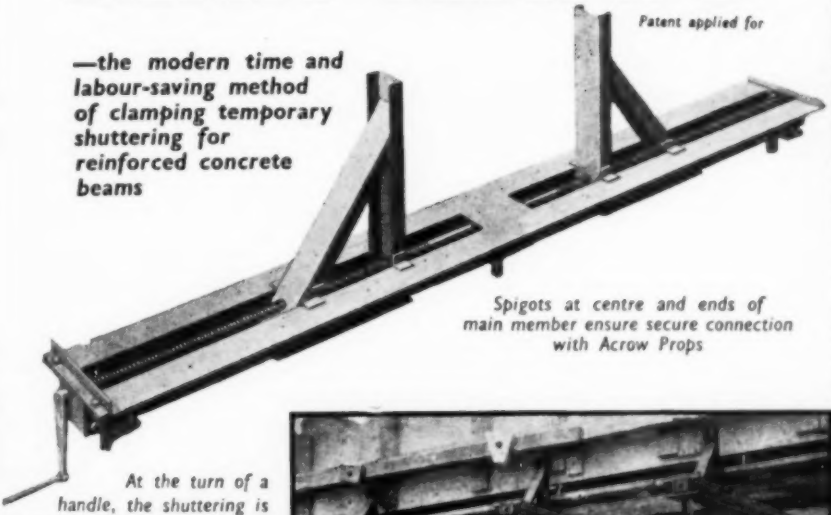

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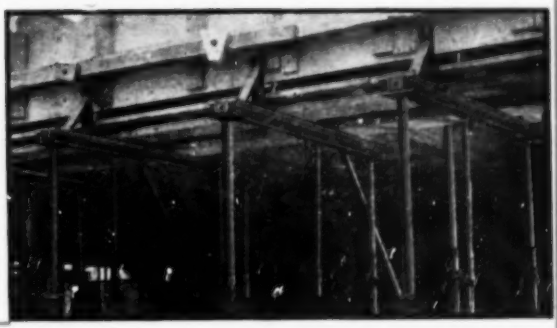

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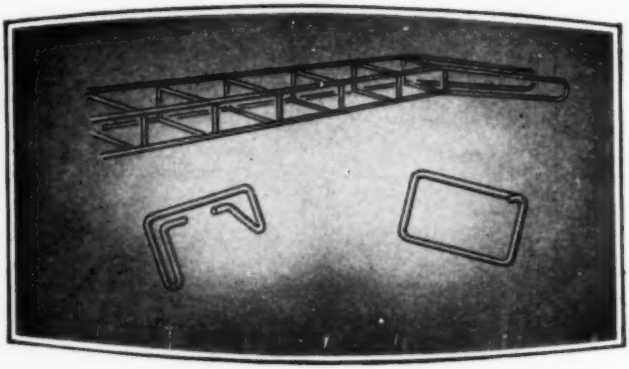

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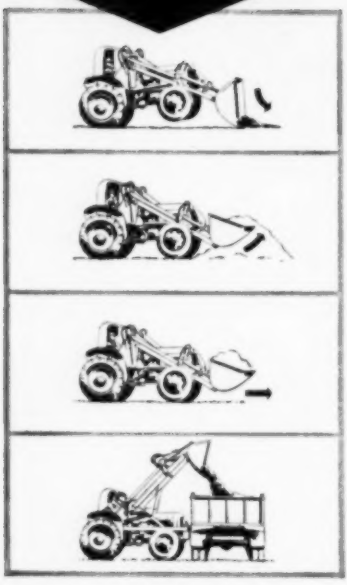

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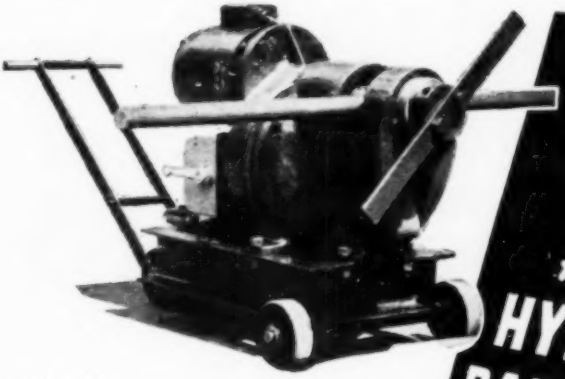

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Volume XLVIII, No. 7. LONDON, JULY, 1953.

EDITORIAL NOTES

Theory and the Engineer.

NOT all constructional engineers achieve much more than a slight acquaintance with the full possibilities of structural theory, for any one branch of theory gives almost unlimited scope for the application of analytical ingenuity and mathematical virtuosity. Rigid frames, domes and shells, columns, shear webs, prestressed concrete, fatigue, the theory of plastic design, are among the subjects in which each step forward seems merely to disclose fresh theoretical problems awaiting solution. Practical difficulties of construction are overcome and progress in the use of new forms and new materials is made in much the same way as architects in classical and mediæval times evolved new methods, when, by all accounts, there was little or no theory to guide them. The major advances in constructional methods have been due to improved and new materials and processes rather than to more abstruse methods of calculation. No engineer will dispute the broad truth of this assessment. For example, the Dome of Discovery at the Festival of Britain was designed and erected before the theoretical calculations were completed, as the responsible engineer revealed when describing this unique structure at a meeting of the Institution of Civil Engineers.* No eighth-order differential equations, no rigid-frame theory in three dimensions, no strain energy or other theories or abstruse mathematics were brought to bear on the problem before the work started—the dome was merely an architect's idea and an engineer's solution. It is valuable for young engineers who are inclined to be obsessed with mathematics to remember that arches were built before Müller-Breslau published his theory, and that skyscrapers existed before the moment-distribution method of analysis was devised. Such masterpieces as the lantern tower at Ely Cathedral might never have been accomplished if the fourteenth-century architects or monks had been fully aware of the difficulties which they had set themselves to surmount. Their work can have owed nothing to the differential calculus, which was not invented until three hundred years after their time; there was then no column theory, no theory of simple bending, not even the parallelogram of forces. This assumption of a complete absence of theory in mediaeval construction is reaffirmed in a recent review † of the past

* Gilbert Roberts. "The Structural Design of The Dome of Discovery." I.C.E. Journal. Oct. 1951, p. 377.

† S. B. Hamilton. "The Historical Development of Structural Theory." I.C.E. meeting, 6 May, 1952.

three hundred years of the development of structural theory; the author of this paper nevertheless suggests that the parallelogram of forces was foreshadowed about 2500 years ago in the "Mechanics" of Aristotle. Whether Aristotle completely understood the matter may never be fully established, but it is beyond dispute that a vast repository of ancient knowledge was lost when the library at Alexandria was destroyed in the seventh century. (Not everything perished; for example, the Elements of Euclid survived all the barbarian outrages of the dark centuries.) It is likely that more of theoretical mechanics may have been known in ancient times than the bare principles written down by Archimedes and other philosophers of the period, for, although the master builders of old depended on a practical knowledge of their materials and an instinct for design, a complete ignorance of theoretical principles was hardly possible; it is not likely that any book on construction other than Vitruvius's was known in the Middle Ages, and that to a few only. It may therefore be surmised that some theory was passed orally from master to pupil.

The engineer to-day must still rely very largely on what he can carry in his head. He must refuse to be "blinded with science". His perception of the bare rules and elements of constructional theory must never be obscured by the intricacies of analysis, nor must his vision of practical possibilities be clouded by too close a view of the difficulties that result from applications of the more profound mathematics and physics.

In the early days of railway engineering, locomotive coupling-rods which spread the torque between the driving wheels were designed on a purely static basis, and it was only the practical experience of failures at high speed which led Osborne Reynolds *, about seventy years ago, to prove by analysis that the coupling-rods were exposed to very heavy dynamic forces and that at high speed they could be expected to fail before any other part of the locomotive. In that case the advanced theory of one of the most renowned natural philosophers of his day contributed in no way to the broad outlines of locomotive design but, by showing that the comparatively trivial refinement of changing the shape of coupling-rods from rectangular to H section would effect an immediate and substantial reduction in the inertia stresses, scientific theory enabled the wheels of an engineer's machine to turn a little faster than before.

Progress in design and construction will continue to depend more on ideas and imagination and on new materials and methods than on analysis—on practical men and slide-rule calculations rather than on the output of the differential analyser and the electronic digital computing machine. The power of mathematical techniques and the capacity of mechanical computers can be usefully applied to improve and refine the product of a designer's inspiration, but they are not in themselves creative instruments. The engineer must therefore keep well informed on novelties of practical construction no less than on the progress of theory. His need is for a balanced outlook, and for sources of information which will help him to maintain a proper balance between theory and practice.

* "On the Fundamental Limitations to Speed." The Engineer, Nov. 18, 1881.

Influence Lines for Prismatic Continuous Beams.

By ALBERT E. HOLDAWAY, B.Sc., Ph.D., A.M.I.Struct.E.

THE basis of this method of calculating the ordinates of influence lines is the theorem of reciprocal deflections due to Müller-Breslau. A discontinuity dependent on the influence line required (for moments, reactions, shears, etc.), is introduced at the desired section, and the moments at the supports caused by this discontinuity are calculated by any method—moment-distribution is usually the most convenient. Using these moments, the ordinates of the influence line can be calculated from the deflections of a conjugate beam on which the load is assumed to be the diagram of the moments at the supports. The deflections are calculated as follows.

The deflection at any point x (*Fig.* 1) is $EI\Delta = \dfrac{Wx}{3l^2}(l^2 - x^2)$. Substituting

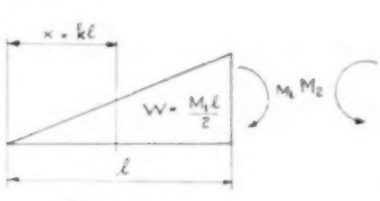

Fig. 1.

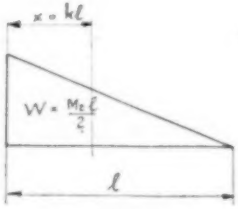

Fig. 2.

TABLE I.

k =	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
C_1 =	0.099	0.192	0.273	0.336	0.375	0.384	0.357	0.288	0.171	0
C_2 =	0.171	0.288	0.357	0.384	0.375	0.336	0.273	0.192	0.099	0

$\dfrac{M_1 l}{2}$ for W, and kl for x, and assuming that E is 1 as only the relative deflections and not the actual deflections are required,

$$\Delta = \frac{M_1 l}{6K} k(1 - k^2) \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where $K = \dfrac{I}{l}$, that is the stiffness of the span considered.

If x is measured as shown in *Fig.* 2 then $(1 - k)$ may be substituted for k and

$$\Delta = \frac{M_2 l}{6K}(2k - 3k^2 + k^3) \quad . \quad . \quad . \quad . \quad (2)$$

Let $C_1 = k(1 - k^2)$ and $C_2 = (2k - 3k^2 + k^3)$, then the total deflection due to M_1 and M_2, which is the ordinate of the influence line, is

$$\Delta_T = \frac{l}{6K}(M_1 C_1 + M_2 C_2) \quad . \quad . \quad . \quad . \quad (3)$$

C_1 and C_2 are constants for any values of k, and values for one-tenth points of the span are given in *Table* 1.

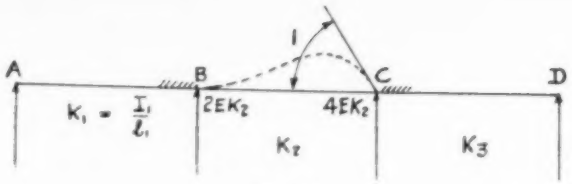

Fig. 3.

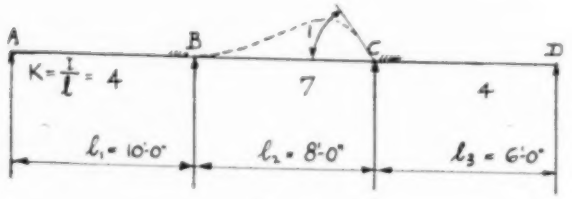

Fig. 4.

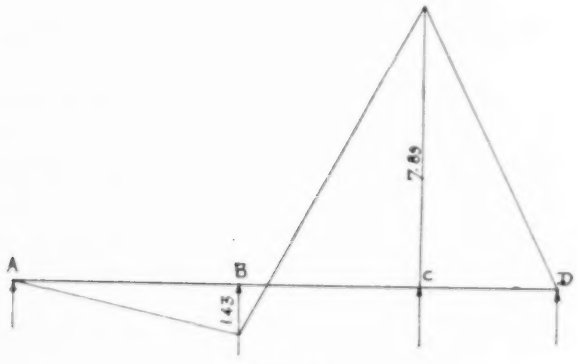

Fig. 5.

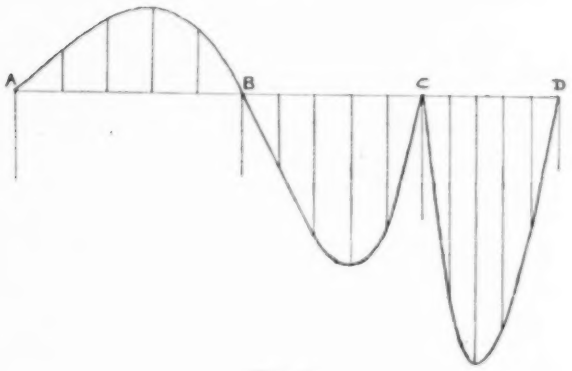

Fig. 6.

TABLE II.

A	B	C	D
	+14	+28	
-4.2	- 9.8	- 19.6	- 8.4
	- 9.8	- 4.9	
+2.94	+ 6.86	+ 3.43	+ 1.47
	+ 1.72	+ 3.43	
-0.52	- 1.20	- 2.40	- 1.03
	- 1.20	-0.60	
+0.36	+0.84	+0.42	+0.18
	+0.21	+0.42	
-0.06	-0.15	-0.29	-0.13
	-0.15	-0.07	
+0.05	+0.10	+0.05	+0.02
- 1.43	+ 1.43	+ 7.89	- 7.89

Influence Lines for Bending Moments.

The discontinuity to be introduced to obtain the influence lines for bending moments is a unit angular discontinuity. To obtain the influence lines for the moment at support C, the unit angular discontinuity is introduced as shown in *Fig.* 3. The beam BC is assumed to be cut at C and fixed at B and a unit rotation is given to the end C, thus setting up moments of $4EK_2$ at C and $2EK_2$ at B. These moments are then distributed through the continuous beam ABCD. It is not, however, necessary to introduce the unit angular discontinuity in span BC only. It may be introduced in span CD, and if D is freely supported the moments will be $3EK_3$ at C and zero at D. This has the advantage that there is then only one fixed-end moment to distribute. The final moments are identical in both cases. If desired, the unit angular discontinuity may be introduced in both spans

TABLE III.

Span						
	K =			0·2	0·4	0·6	0·8
	C_1 =			0·192	0·336	0·384	0·288
	C_2 =			0·288	0·384	0·336	0·192
l_1	$\frac{M_1 l_1}{6K_1}$ = $\frac{1.43\times10}{6\times4}$	= 0·596		0·115	0·200	0·229	0.172
	$\frac{M_2 l_1}{6K_1}$ = 0			-	-	-	-
			I.L.O.	0·115	0·200	0·229	0.172
l_2	$\frac{M_1 l_2}{6K_2}$ = $\frac{-7.89\times8}{6\times7}$	= -1.50		-0·288	-0·504	-0·576	-0·432
	$\frac{M_2 l_2}{6K_2}$ = $\frac{1.43\times8}{6\times7}$	= 0·272		+0·078	+0·105	+0·092	+0·052
			I.L.O.	-0·210	-0·399	-0·484	-0·380
l_3	$\frac{M_1 l_3}{6K_3}$ = 0			-	-	-	-
	$\frac{M_2 l_3}{6K_3}$ = $\frac{-7.89\times6}{6\times4}$	= -1.973		-0·568	-0·757	-0·663	-0·379
			I.L.O.	-0·568	-0·757	-0·663	-0·379

adjoining the support considered, the sum being equal to unity, but by doing so more work is entailed in distributing the fixed-end moments.

An example (*Fig.* 4) shows the application of the method. The ordinates of the influence line for the moment at the support C are required for the beam ABCD of which the ends A and D are assumed to be freely supported.

The discontinuity required is a unit rotation at C, which produces fixed-end moments of $2K_2$ at B, that is $2(7) = 14$, and $4K_2$ at C, that is 28, assuming E to be unity. The fixed-end moments are distributed in *Table* II and the bending-moment diagram is given in *Fig.* 5.

The ordinates of the influence lines are calculated in *Table* III, and the influence line is shown in *Fig.* 6.

The method can be applied with particular facility to the calculation of influence lines for reaction, shear, slope, and deflection. It may also be adopted for use with non-prismatic beams and rigid frames.

Deterioration of Concrete by Sewage.

In view of the fact that the Metropolitan Drainage Board of Auckland, New Zealand, proposes to construct in concrete during the next ten years some 35 miles of main and outfall sewers, and the ancillary treatment tanks, Mr. J. P. Porter, M.I.C.E., Chief Engineer of the Board, has submitted a report on the use of concrete for these works.

The report states that in Capetown, Cairo, the principal cities of Australia, and elsewhere, severe damage to concrete linings to sewers has occurred due to the presence of sulphide above the normal liquid level. It is commonly accepted that this type of damage is most likely to occur in very long sewers laid at flat gradients. In these cases the sewage becomes septic, and the air above the flowing liquid becomes impregnated with sulphur dioxide and other noxious gases. These conditions are likely to be aggravated substantially where strong trade wastes are present, and particularly where the trade wastes contain sulphides in high concentrations. So far no damage of this type has been reported in Auckland, probably because existing main sewers are relatively short and because temperatures are not unduly high.

During the years 1937 to 1940, Mr. Porter (then in the Engineer's Department of the London County Council) had experience of deterioration of concrete by sulphide action to a marked degree. Several double-compartment aeration channels more than 6000 ft. in total length were built by the London County Council in high-quality Portland cement concrete in 1931. The liquid being treated, namely settled and partly-aerated sewage, flowed through the enclosed lower compartments in such a way that there was a space 6 in. deep between the top of the liquid and the concrete roof. When the tanks were inspected in 1937, it was found that, while all the concrete below sewage-level was in first-class condition, the concrete subjected to attack by damp air impregnated with sulphur given off at liquid level (that is the roof and 6 in. of each side wall) had after six years become soft to a depth of $\frac{1}{2}$ in. The reinforcement was exposed, and rusting was rapidly occurring. A feature of sulphide deterioration of concrete in sewers and sewage treatment tanks, proved both in London and in Capetown, is that it is greatly aggravated by particular types of bacteria known as "sulphur bacteria".

The report points out that pozzolana-cements are more resistant to chemical attack and recommends that pozzolana-cement be used for the new sewage works, using deposits of pozzolana available in New Zealand.

Plashet County Secondary School for Girls, East Ham, London.

REINFORCED CONCRETE AND PRESTRESSED CONCRETE.

THIS school (*Fig.* 1) for 680 girls is on part of a site of about twelve acres most of which is occupied by houses which could not be demolished at the time of building the school. The ground floor accommodates cloakrooms, lavatories, kitchen, gymnasium, and assembly halls; the staff rooms are on a mezzanine floor; the six upper floors contain classrooms and rooms for practical instruction. The construction combines precast and in-situ prestressed concrete and reinforced concrete.

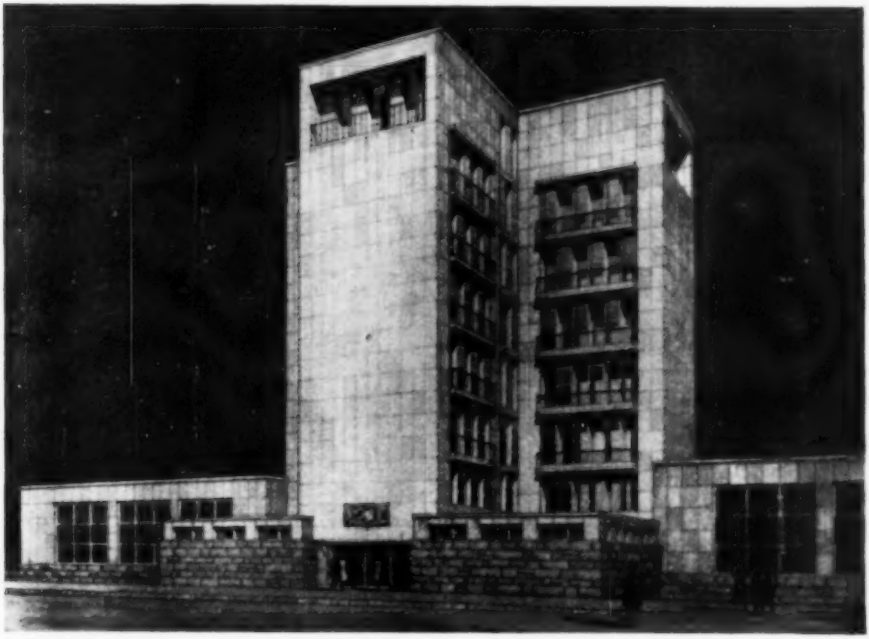

Fig. 1.—Architect's Drawing of Part of School.

The area of the basement was excavated to a depth below ground-level sufficient to extend about 1 ft. into London clay. A 3-in. layer of concrete was then laid, followed by 2 ft. of plain concrete with a raised perimeter in the upper surface of which a groove was formed to receive the retaining walls. The retaining walls are of prestressed concrete, post-tensioned by the Lee-McCall system. The high-tensile bars were bent in the shape of a U and tensioned in pairs from the outer edge of the toe and from the top of the wall. These bars are placed with an eccentricity such that the resulting forces offset the bending moments caused by the two stages of loading considered, namely (a) during construction, with partial back-fill, and (b) the completed structure fully loaded. The diameters and spacing of the bars vary from $\frac{7}{8}$ in. at 2-ft. 2-in. centres to $1\frac{1}{4}$ in. at 1-ft. centres. An outer wall of brickwork coated with water-proofed cement was used in place of shutters for the lower parts of the wall, and metal shutters for the inner face. The wall is shown during construction

in *Fig.* 2, and the completed wall in *Fig.* 3.

The column bases, the main columns extending to the first floor, and the transverse beams connecting the columns were post-tensioned by the same system, and it is estimated that 34 tons of steel were saved compared with similar construction in reinforced concrete.

The roofs over the kitchens and lavatories on the ground floor, the walls surrounding the lift-shafts, and the dividing walls are of normal reinforced concrete, but as many of the members on the upper six floors are repeated as much as possible of this work was precast.

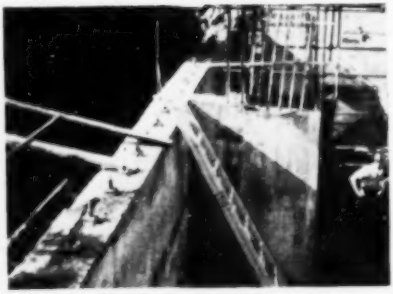

Fig. 3.—Part of Retaining Wall.

Fig. 2.—Method of Building Retaining Wall.

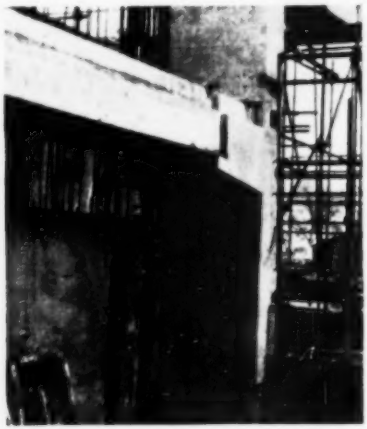

Fig. 4.—A Frame in a Classroom.

Each classroom consists of two sets of frames connected by two window frames each 20 ft. long by 10 ft. high, two in-situ concrete end walls, and a precast floor. The posts are joined 5 ft. above floor-level with a spliced and bolted joint and the beams are joined to the brackets of each post by a metal hinge embedded in the members and connected by two 1½-in. bolts. The window frames are connected to the posts by ⅝-in. bolts, the heads of which are hidden in recesses in the window frame. The posts and beams are connected to the in-situ walls by bolts and plate washers 3 in. by 3 in. by ¼ in. Some details are shown in *Figs.* 4 to 7.

The floors are prestressed precast hollow members, 8 in. thick and of 20-ft. span,

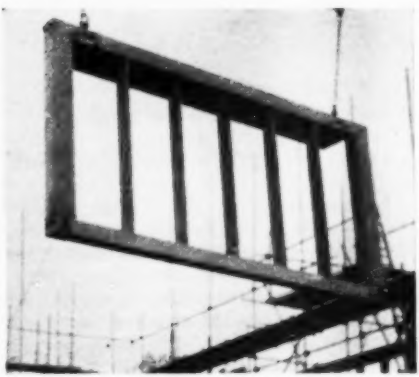

Fig. 5.—Window Frame being Hoisted into Position.

Fig. 6.—Joint between Posts.

Fig. 7.—Hinge between Post and Precast Beam.

supported by the frames. A similar construction is used for the "practical" room in the north wing, except that here the members are considerably larger due to increased spans and heavier loads.

Above first-floor level the stairs are all of prestressed precast concrete using post-tensioned high-tensile bars.

A test of a flight of these stairs was described in this journal for March, 1953.

The use of precast members enabled a complete floor to be built in seven working days. All the members were lifted into position by a 7-tons electric derrick crane mounted on steel staging.

The lower part of the building has a plinth of rough-faced Portland stone, and the upper part is to be covered with slabs of Portland stone about 2½ in. thick fixed to the concrete by dowel cramps and dovetailed metal slots embedded in the concrete.

The architect is Mr. George Whitby, M.B.E., A.R.I.B.A., and the consulting engineer who designed the prestressed concrete and the reinforced concrete work was Mr. R. F. Galbraith, B.Sc., A.M.I.C.E., M.I.Struct.E. The main contractors were Messrs. Bernard Sunley & Sons, Ltd. Stent Precast Concrete, Ltd., made the precast post-tensioned members and the prestressed floor members were supplied by Concrete, Ltd. The high-tensile bars and jacking equipment for the post-tensioned work were supplied by McCalls Macalloy, Ltd., and Scotia Engineering, Ltd., supplied the hinges for the frames.

Lectures on Concrete Roads and Soil Stabilization.

Two courses of lectures on concrete with reference to the construction of roads will be held at the Road Research Laboratory, Harmondsworth, during the periods November 17 to November 26 and December 1 to December 10, 1953. A fee of £10 10s. will be charged for each course, further details of which may be obtained from the Director, Road Research Laboratory, Harmondsworth, Middlesex.

Two three-day courses on the stabilization of soil with cement have been arranged by the Road Research Laboratory and the Cement & Concrete Association, and will be held on August 10 to August 12 and August 12 to August 14, 1953, at the Association's Training Centre, Wrexham Place, Stoke Poges, Buckinghamshire. There will be no fee for these courses, and application to attend should be made to the Cement & Concrete Association, 52 Grosvenor Gardens, London, S.W.1.

Two Schools in Yorkshire.

THE two schools described in the following have suspended floors and roofs, of a patented composite in-situ and precast construction, supported by two-pin frames except where load-bearing walls occur. The floors and flat roofs comprise precast beams, 6 in. deep by 4 in. wide at 1 ft. 8 in. centres, supporting 2-in. slabs of foamed-slag concrete on which is laid a topping of dense concrete so that the total depth is 9 in. Stirrups projecting from the top of the precast beams ensure that the topping and the beams act together. The beams of the in-situ frames are cast in two stages; first to the soffit of the precast beams, which are laid with a bearing of about 3 in. on the main beams when the concrete has hardened, and secondly the upper portion of the main beam is cast with the topping to the floor so that the topping forms a compression flange for the main beam. The method of construction is known as the Myko system. The structural design of both schools is by Messrs. Hajnal & Myers.

Brook School, Sheffield.

This is a secondary modern school, now nearing completion, which will accommodate 680 pupils in two two-story classroom wings, one of which is shown in

Fig. 1.—A Classroom Wing at Brook School, Sheffield.

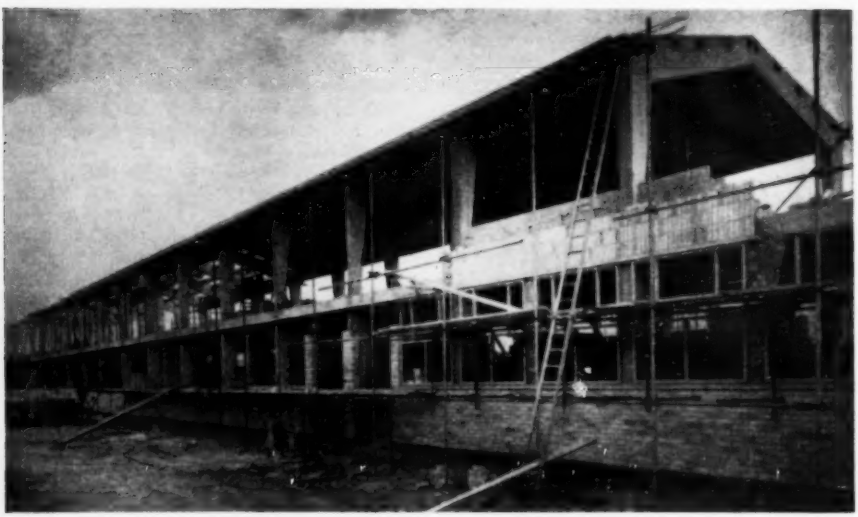

Fig. 2.—Construction of Two-story Two-pin Frames at Brook School, Sheffield.

Fig. 1. Buildings adjoining the classrooms include an assembly hall, gymnasium, dining room, and kitchen. The two classroom wings, 240 ft. by 24 ft., are parallel and separated by open areas with cloakrooms at intervals connecting the wings. The first floors of the classrooms are as described previously; the roofs are hipped, with slopes of 15 deg. to the horizontal, and comprise precast purlins, 8 in. deep by 5 in. wide, supporting 2-in. wood-wool slabs which are covered with a screed of cement and sand ½ in. thick. The purlins have timber strips, 1¼ in. by 1 in., cast in the tops and bottoms, the wood-wool slabs being fixed to the upper strips; to the lower strips are fixed 2-in. by 1-in. battens, at intervals of 1 ft. 6 in., to carry ceiling-boards. The floors and roofs are supported by two two-pin frames, one above the other (*Fig.* 3); these are at intervals of 13 ft. 4 in. and span 24 ft. The first-floor beams were cast in two stages as previously described and the precast floor-beams and external lintels were concreted in the second lift. Pockets were formed in the roof beams to receive the ends of the purlins. One of the classroom wings during construction is shown in *Fig.* 2. The two-pin hipped frames in the assembly hall have a span of 44 ft. and a height of 21 ft.

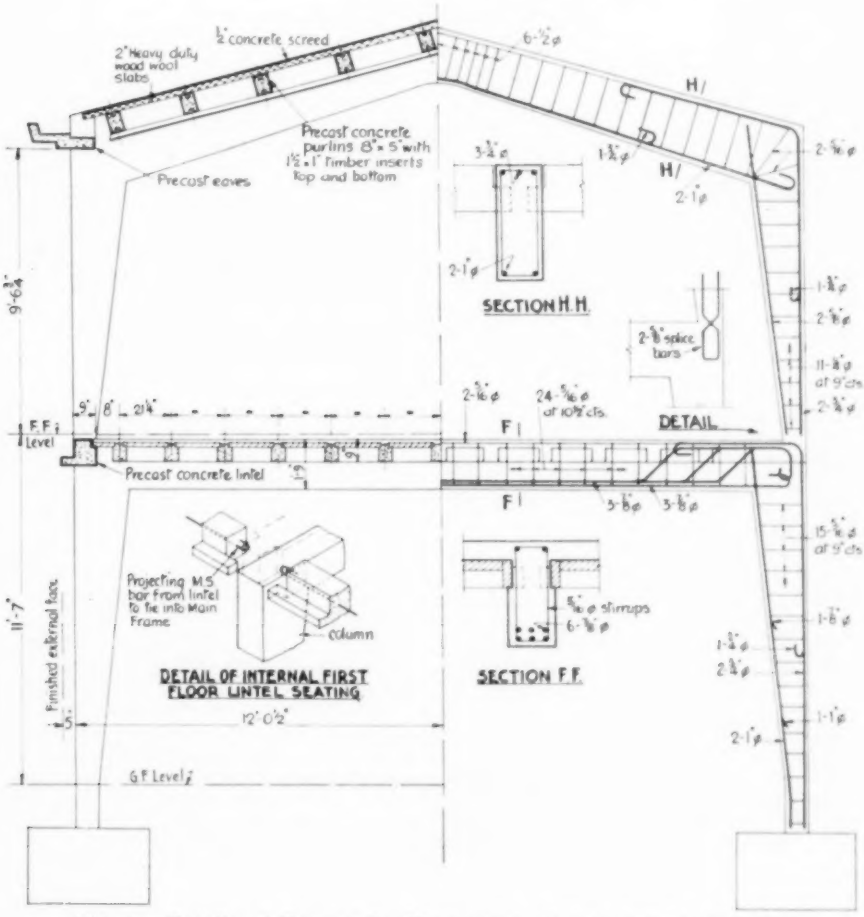

Fig. 3.—Details of Frames in Classrooms, Brook School, Sheffield.

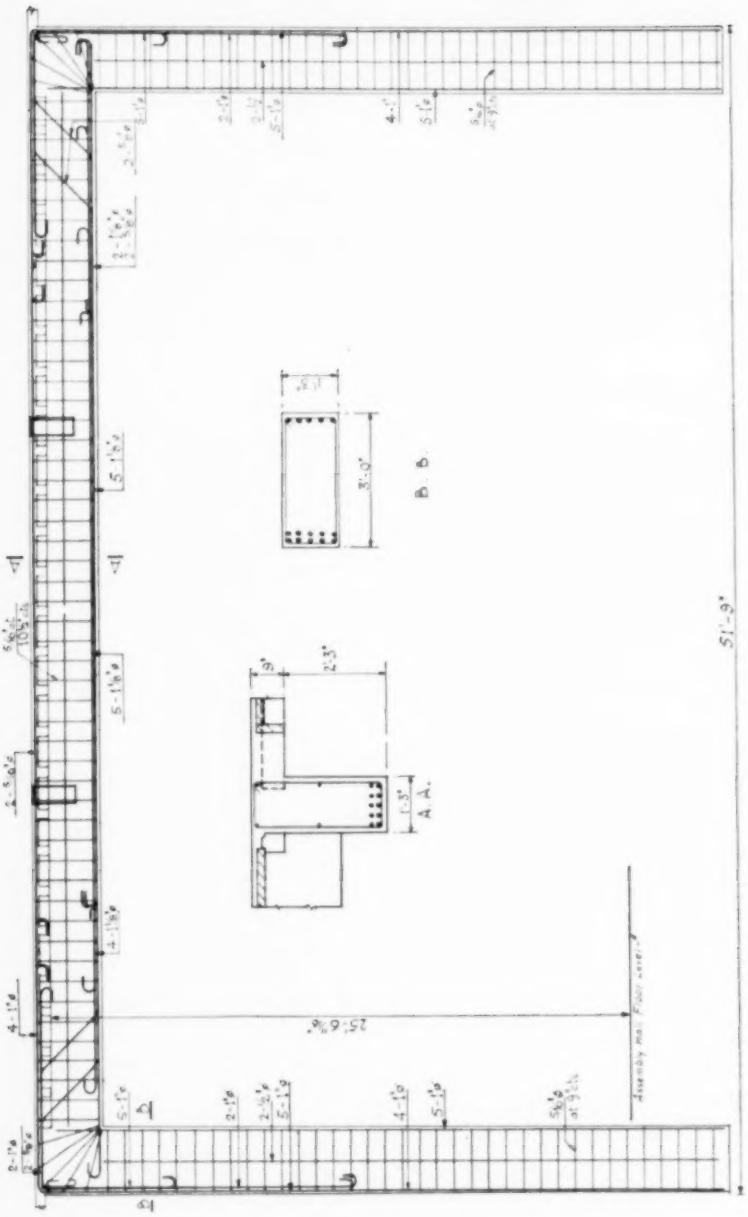

Fig. 4.—Frame in Assembly Hall at School at Dewsbury.

Fig. 5.—Earlsheaton School, Dewsbury.

The architects are Messrs. Hadfield, Cawkwell & Davidson, F./A.R.I.B.A., the general contractors are the Public Works Department of the Sheffield City Council, and Messrs. George Greenwood & Sons were responsible for the reinforced concrete work.

Earlsheaton School, Dewsbury.

This County secondary school (*Fig.* 5) for 600 pupils comprises single-story and two-story classrooms, assembly hall, gymnasium, dining-room and kitchen arranged roughly in the shape of a letter H. The construction is similar to that described previously except that the frames have horizontal upper members and consequently all the roofs are of composite construction. The single-story two-pin frames (*Fig.* 4) in the hall have a span of 51 ft. and a height of 25 ft. 6 in. from the floor to the soffit of the roof; those in the gymnasium have a span of 40 ft. and a height of 18 ft. 3 in. The floors and roofs of the classrooms are supported by two-story two-pin frames where load-bearing walls do not occur. Each of the frames has a span of 24 ft. and a total height of about 26 ft. In these frames there are pin-joints only at the bases of the columns.

The architect is Mr. J. Fogden, A.R.I.B.A., Borough Architect, Dewsbury, the general contractors are Messrs. George Horsefall & Son, and Messrs. George Greenwood & Sons were responsible for the reinforced concrete work.

The Strength of Grouted Concrete.

In the article on the foundation for a large hammer at Huntington, U.S.A., described in our number for April, 1953, it was stated that some cubes of grouted concrete had a compressive strength of 13,000 lb. per square inch at 128 days. Mr. J. H. A. Crockett, A.M.Inst.C.E., the consulting engineer for the foundations, informs us that the results of further compressive tests are now available.

While the upper block was being concreted, 6-in. by 12-in. cylinders were made for testing at ages up to one year. The results were as follows in lb. per square inch: At 60 days, 9300 lb.; 100 days, 11,000 lb.; 180 days, 13,500 lb.; 360 days, 16,000 lb. (these figures are the crushing strengths of the cylinders plus 25 per cent. to represent the higher strengths obtainable on cubes compared with cylinders). It appears that the strength is probably still increasing after one year. The cylinders were stored at a slightly higher temperature than is customary in Great Britain. The grout comprised Portland cement, finely-divided pozzolanic material (Alfesil), an "intrusion aid," and water. It is claimed that the pozzolanic material (which is an extremely finely-divided fly-ash obtained from the electrostatic dust-precipitators in electricity power station flues) tends to prevent agglomeration of cement particles and to decrease "bleeding." Several functions are also claimed for the "intrusion aid," such as that it acts as a fluidifier, that it tends to hold the solid constituents in suspension, that it somewhat neutralises the effects of drying shrinkage and that, as a protective colloid, it prevents early stiffening of the grout. As a result of research at the University of California on behalf of the Prepakt Concrete Company, the proportions of the grout were 9 parts of Portland cement, 1 part of fly-ash, and 6 parts of sand plus the "intrusion aid" in the proportion of 1 per cent. by weight of the cement and fly-ash. The ratio of water to cement plus fly-ash was generally 0·38.

A School in a Mining District.

DESIGNED TO ALLOW FOR SETTLEMENT.

THE school shown in *Fig.* 1 is at Rossington, Yorkshire, and comprises three wings arranged in the form of a letter Y. Although it is founded on compact dry sand, the building is divided into separate parts, each about 60 ft. by 40 ft., to reduce the possibility of damage caused by subsidence due to mining. The roofs are of hollow-tiles and the floors of in-situ slabs supported by load-bearing walls which, except for those over the underground boiler-house, are on reinforced concrete foundation beams. These beams, which are 2 ft. 6 in. deep and generally contain four 1-in. bars near the top and bottom, with ⅜-in. stirrups at 6-in. centres, are as narrow as possible consistent with the bearing strength of the ground of 30 cwt. per square foot. Thus, should there be any subsidence, the ground may be overloaded and the beams will settle, so reducing their span over the area which has subsided. Furthermore it is considered that this arrangement will reduce the possibility of differential settlement. Between the various parts of the structure there are joints 6 in. wide which are masked in the walls by expanded metal fixed to vertical wooden battens, plastered internally and rendered externally to match the adjacent wall finishes. At the connecting openings between the units the suspended concrete floors are cantilevered slightly, reducing the joint at these points to 1 in., and this gap is sealed with fibreboard.

The ground-floor slab is carried on brick sleeper-walls supported by foundation beams. The ground, the finished level of which is at the top of the beams, is covered with a thin layer of concrete. The cavity between this layer and the ground floor is used for services and crawlways, and was useful when the retractable steel shutters for the floor slab were being removed.

The hollow-tile roofs vary in depths from 6½ in. to 8½ in., with a 2½-in. topping in all cases, and as far as possible span from wall to wall without beams. A continuous beam, 1 ft. to 1 ft. 6 in. deep by 8½ in. wide, was formed at roof level around each of the separate parts of the structure. The main purpose of this beam is to give lateral stiffness to the roof, but it also serves as a lintel over window and door openings. A parapet in the form of a 9-in. wall comprising two leaves of 3-in. hollow blocks with concrete placed between them is secured to the roof by vertical bars placed in the concrete.

Fig. 1.—Front Elevation.

The concrete throughout the work is a 1 : 2 : 4 mixture (by volume) with crushed-stone aggregate of ¾ in. maximum size. A crushing strength of at least 3000 lb. per square inch was obtained at an age of 28 days.

The architects are Messrs. Johnson & Crabtree, in collaboration with Mr. Hubert Bennett, County Architect of the West Riding; the heating and electrical consultants are Messrs. Phillips, Son & Norfolk. The foundations and roof were designed by Messrs. McCall & Co. (Sheffield), Ltd., and the general contractors are Messrs. Frank Haslam, Ltd.

A Technical College at Wrexham.

THE technical college at Wrexham, Denbighshire (*Fig.* 1), comprises a number of buildings arranged on three sides of a rectangle and accommodating classrooms and laboratories, domestic science, bakery, arts and crafts, and commercial departments, offices, cloakrooms, dining hall and kitchen, library, conference room, lecture theatre, exhibition room, and main entrance hall, with separate buildings for workshops, gymnasium, and music rooms. The two wings are about 240 ft. long. The wing in the background of *Fig.* 1 is 36 ft. wide. The wing in the foreground is formed by three buildings, of which that on the right, comprising the dining hall and kitchen, is about 60 ft. square, the intermediate building is 36 ft. wide, and the end building is 62 ft. wide and projects about 55 ft. to form the main entrance. The building connecting the two wings is about 540 ft. long, of which about 115 ft. projects (in the foreground of *Fig.* 1) to form an assembly hall. This building is about 62 ft. wide. Connected to the dining hall by a covered way are the gymnasium and music rooms (to the right foreground of *Fig.* 1) accommodated in a building about 150 ft. long by 70 ft. wide. The workshops, about 140 ft. by 75 ft., are connected to the other wing.

Apart from the assembly hall, gymnasium, and music rooms, and the upper portion of the workshops, which are of structural steel, the buildings have reinforced concrete frames filled in with brickwork. As mining occurs in the vicinity, although not under the site, a foundation is provided which gives protection against the effects of possible subsidence. The ground is a marly clay with a safe bearing pressure of 1½ tons per square foot. The foundations consist of inverted tee-beams 4 ft. 6 in. deep with ribs 11-in. wide reinforced with two 1¼-in. bars top and bottom, and foundation slabs 2 ft. 6 in. wide. The beams distribute the loads from the walls and the columns, which are at 10 ft. centres.

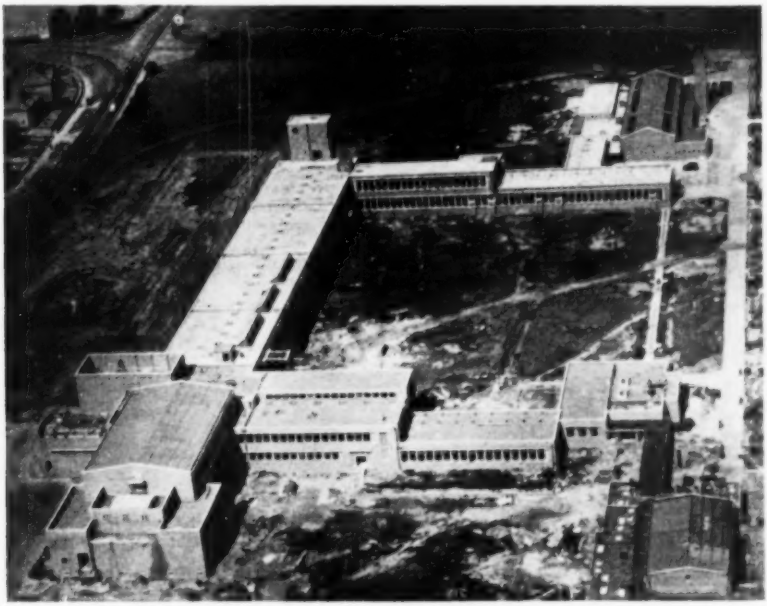

Fig. 1.

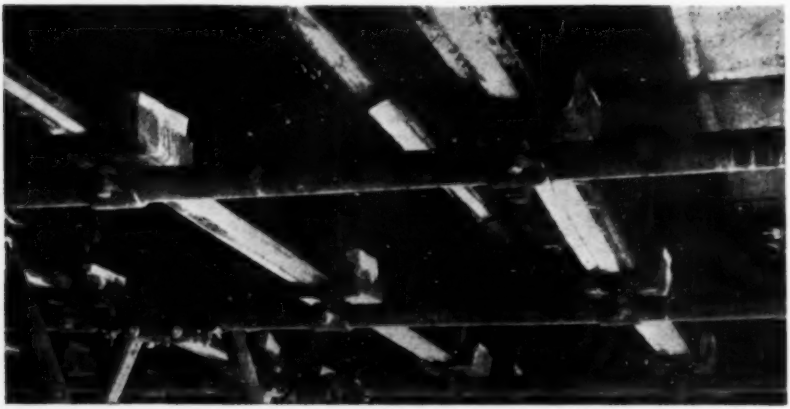

Fig. 2.—Steel Moulds for Beams supported by Shoes on Steel Scaffold Tubes.

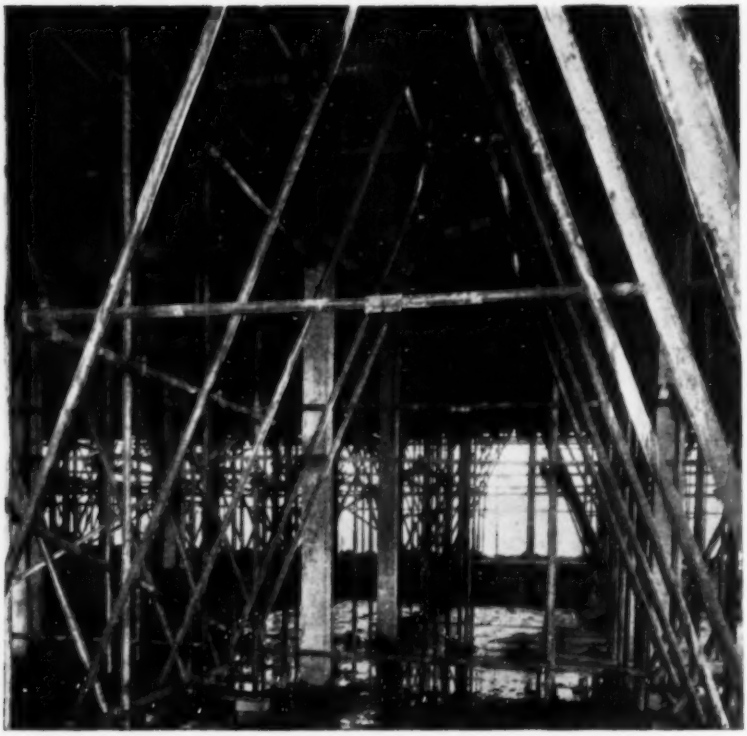

Fig. 3.—Movable Frames supporting Floor Centering.

Joints are provided through the buildings at about 90 ft. centres and between the various buildings. Twin columns connected to a continuous foundation are used to allow movement.

The ground floors are suspended and consist of precast inverted trough-shaped members 1 ft. 6 in. wide by 5 in. or 7 in. deep. These members are supported by precast beams, 9 in. by 9 in., resting on brick piers at 5 ft. centres. The space under the suspended ground floors is used for ducts for the main services.

use of timber a channel shoe was devised which was welded to a standard putlog coupler to enable the steel moulds to be clamped to steel scaffold tubes (*Fig.* 2).

Because of the large area of trough construction (about 8000 sq. yd.) movable frames (*Fig.* 3) were used to support portions of the floors and roofs up to 60 ft. long by the width of the building. The frames, which were made of steel scaffolding, were supported on jacks and rollers so that they could be lowered and moved to the next bay in one piece.

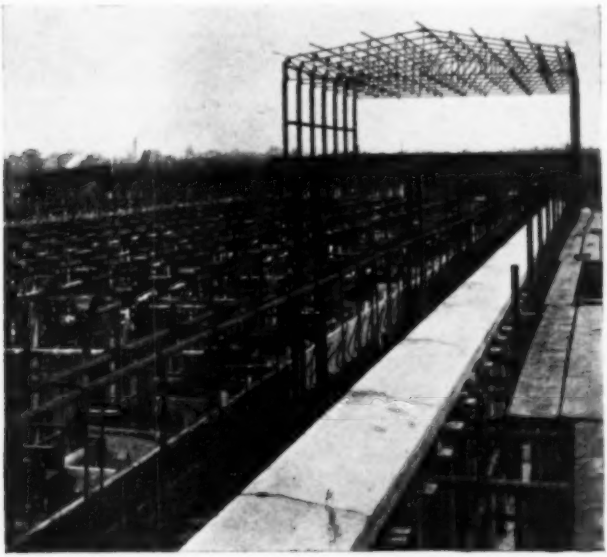

Fig. 4.—Precast Window Heads.

Except where cost did not justify its use, the suspended first floors and roofs comprise in-situ troughs supported by longitudinal outer wall-beams and corridor-beams. Generally the spans of the troughs are 26 ft., and the overall depth is 1 ft. 5 in. made up of a 2-in. slab and ribs 1 ft. 3 in. deep. The ribs are at 2 ft. centres, 3½ in. wide at the bottom and increasing to about 4½ in. wide at the soffit of the slab.

Construction.

The troughs were cast in steel moulds shaped so that the junction of the ribs and the slab is curved. To reduce the

This method enabled a rapid rate of construction to be maintained. To reduce the amount of work on the site, projecting window-heads (*Fig.* 4) which support the outer 4½-in. leaf of brickwork were precast in lengths of about 5 ft. These members have keyed joints and projecting reinforcement so that they could be built in with the longitudinal wall-beams. This arrangement was very successful and had the additional advantage that the colour of the window mullions, which were also precast, could be matched.

For acoustic insulation the floors of the classrooms comprise a reinforced concrete slab 3 in. thick cast on glass wool laid on

the trough floors. Various finishes were then laid on the " floating " floor, including granolithic, precast terrazzo tiles, plastic tiles, rubber, and wooden blocks. The suspended ceilings consist of acoustic tiles hung about 10 in. below the soffit of the troughs, the space between the ceiling and the troughs being used for secondary services. The hangers were supported by bolts fixed in holes formed in the ribs. The floors were designed for an imposed load of 100 lb. per square foot, plus an allowance for partitions. The imposed load on the roof was 30 lb. per square foot and the dead load included an allowance for services and finishes comprising acoustic tiles and a foamed-slag screed waterproofed with rock asphalt on which white spar chippings were sprinkled.

A basement under the workshops has retaining walls 1 ft. 6 in. thick and about 18 ft. deep. The underside of the basement floor is only 1 ft. above the level of ground water, and the construction of sumps for the boilers, which are about 5 ft. below floor level, provided a difficult constructional problem, as pumps did not lower the water level. The sumps were constructed by excavating by hand the waterlogged ground, lowering an open steel box into the excavation, and concreting the top edges of the boxes into the floor. A steel plate was then bolted to the lower edges of each box, the water pumped out, and the concrete sump constructed inside the steel lining.

The roofs of the workshops, gymnasium, and hall are steel trusses with an insulation of reinforced wood-wool slabs 3 in. thick. The roof over the dressing rooms and stage is of precast concrete. The service roads and paved areas are 6-in. slabs reinforced with high-tensile steel fabric.

The concrete is a 1 : 2 : 4 mixture with aggregate of ¾ in. maximum size. The working stresses in the steel and concrete are 18,000 lb. and 1000 lb. per square inch respectively. About 320 tons of mild steel bars, bent to shape before despatch, and 30 tons of high-tensile fabric were used.

Messrs. Saxon, Smith & Partners are the architects, and the design of the reinforced concrete work was carried out by the British Reinforced Concrete Engineering Co., Ltd., who also supplied the reinforcement and steel moulds for the troughs. The contractors were Messrs. Holland & Hannen and Cubitts, Ltd., and the precast floors were supplied by Ferroconcrete (Lancashire), Ltd.

Flexible Joints in Foundations.

REINFORCED concrete struts bracing the pile-caps in the foundations of several large warehouses in Alameda, California, U.S.A., are designed to allow for a settlement of the ground of about 1 ft. 6 in. The building (described in " Engineering News-Record " for March 12, 1953) is supported by columns on piles at about 40-ft. centres but the ground floor, of a flexible form of construction, is laid directly on the compressible ground. In order to avoid unequal settlement of the floor and designing the struts to support part of the load on the floor, the struts, which are 12 in. wide, were cast with keys projecting into slots 8 in. wide in the pile-caps and prevented from bonding to the caps by layers of compressible material placed in the slots. The joint (*Fig.* 1) was designed by Kaiser Engineers who are carrying out the work for the U.S. Navy.

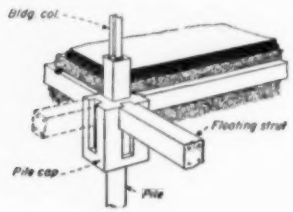

Fig. 1.

Cardinal Griffin School, London.

THIS structure was one of the permanent buildings on the London County Council's Lansbury Estate, Poplar, London, E., which constituted the Architectural Section of the Festival of Britain in the year 1951, and was under construction during the period of the Festival. It has recently been completed by the addition of a dining hall.

The school (*Fig.* 1) comprises a two-story classroom building 212 ft. long by 35 ft. wide and four wings each 67 ft. long by 28 ft. wide containing handicraft rooms, lavatories and cloakrooms, with a boiler house under the eastern wing. At the eastern end of the main building are the entrance hall and assembly hall with a gymnasium 150 ft. long by 42 ft. wide below. At the southern end is the dining wing 100 ft. long by an average of 50 ft. wide.

The structure is in reinforced concrete, the outer walls having brick panels with the concrete columns showing on the external face. These columns are of trapezoidal section of 7 in. maximum width and are spaced at 7 ft. centres; they carry beams and a hollow inverted-trough floor 1 ft. 6 in. deep spanning the full width of 35 ft. A suspended plaster ceiling is provided on the underside and no beams are visible. This form of construction offered advantages in natural lighting in the classrooms and proved to be economical, giving also complete freedom in the position of partitions, etc. A similar form of floor construction was used in the handicraft and dining wings.

Reinforced concrete frames support the roofs, which comprise precast slabs covered by a screed of vermiculite and three layers of felt. The ceilings are plastered on the underside in the case of the classrooms, but, where the passage of noise had to be prevented in the handicraft rooms, asbestos was sprayed on the ceiling; this has proved to be effective.

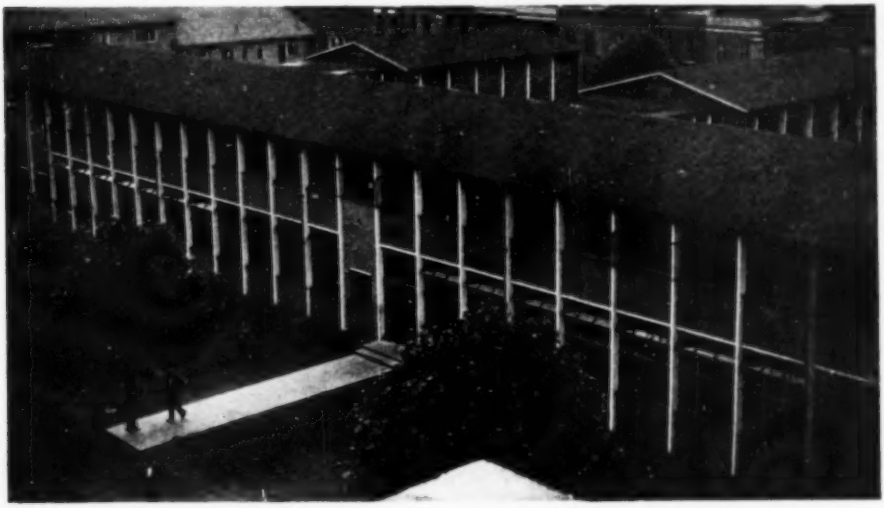

Fig. 1.—The Classrooms.

The floor of the assembly hall comprises a solid reinforced concrete slab on beams spanning 42 ft. The roof comprises asbestos-cement sheets on steel trusses. At the southern end of the hall is a stage with rooms under.

The tower (*Fig.* 2) over the stage has three floors and extends 45 ft. above ground level; the side walls are of the "box" load-bearing type, 18 ft. wide and 36 ft. high. The reinforced concrete

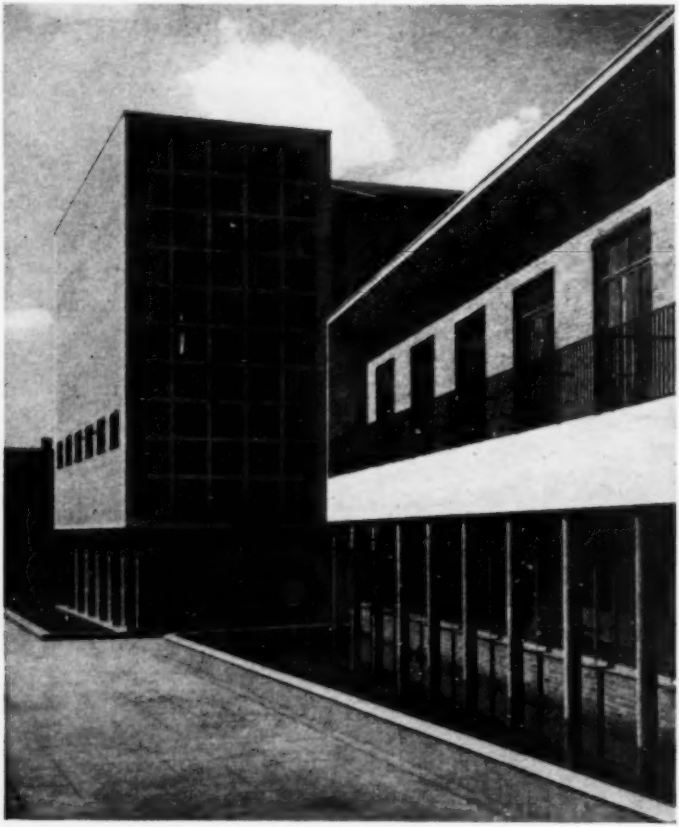

Fig. 2.—The Tower, Dining Wing, and Colonnade.

members in these walls are spaced at about 3 ft. centres vertically and horizontally.

The colonnade erected alongside the assembly hall has circular precast columns 9 in. diameter with a face of marble aggregate cast integrally with the core. The columns are polished, and form a colour contrast to the brickwork and concrete members; they were made by Girlings Ferro-Concrete Co., Ltd., as were also the circular columns in the dining wing (*Fig. 2*) and the precast stairs. The stairs are generally cantilevered from the walls and have a maximum width of 5 ft. 6 in.; the treads are 2 in. thick and the risers 3 in. thick.

The architect was Mr. David Stokes, F.R.I.B.A., the contractors Messrs. C. Miskin & Sons, Ltd., and the structural engineers were Considère Constructions, Ltd.

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Castle Hill School, Ipswich.

PRECAST FACING SLABS.

THE school shown in *Fig.* 1 has recently been completed at Ipswich. The construction consists of a steel frame supporting classrooms on two stories with the assembly hall, cloakrooms, offices, and kitchen as single-story structures. The dimensions of the building are related to a 10-ft. grid with a module of 3 ft. 4 in. longitudinally and 10 in. vertically.

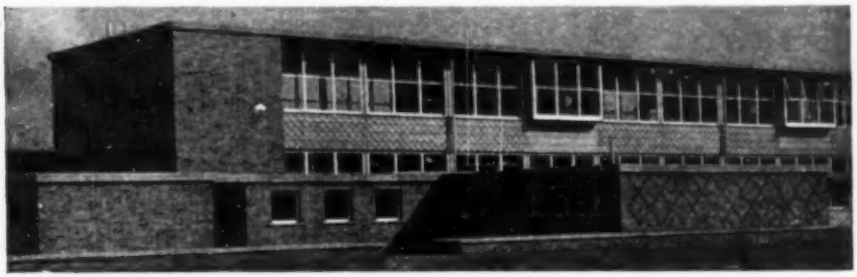

Fig. 1.

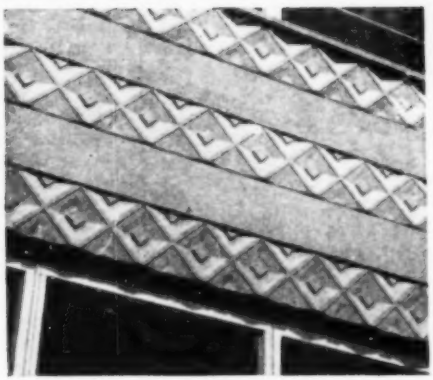

Fig. 2.—Plain and Patterned Precast Slabs.

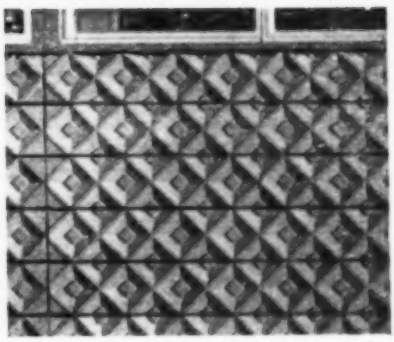

Fig. 3.—Patterned Precast Slabs.

The ground floor is a concrete slab 4 in. thick except under 4½-in. brick partition walls where the thickness is 6 in. The roofs and the first floor are of precast beams. The roof beams are channel shape 10 in. wide by 4 in. deep, and the floor beams are of hollow box-shape 6 in. deep by 6 in. wide. The eaves are of three types. Those extending about 2 ft. beyond the face of the building comprise a solid member 5 in. wide, two channels 10 in. wide, and a small fascia member fixed to the outermost channel by ¼-in. diameter dowels at 10-in. centres (*Fig.* 4). The other two eaves members project only 3 in. and are also shown in *Fig.* 4. The external walls, which are either of precast facing slabs with a cavity and a lining of clinker blocks or of two leaves of brickwork forming an 11-in. wall with a 2-in. cavity, are supported on reinforced concrete foundation beams 12 in. deep by 8 in. wide spanning between the bases for the steel columns.

The precast facing slabs are 10 ft. long

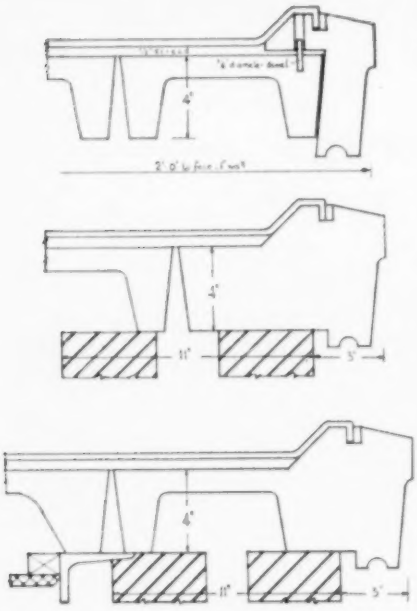

Fig. 4.—Cross Section through Eaves.

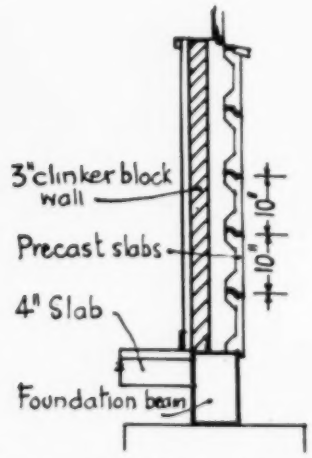

Fig. 5.—Cross Section through External Wall.

by about 10 in. wide by 3 in. thick, the cross section being as shown in *Fig.* 5. Both plain and patterned slabs are used (*Figs.* 2 and 3). On the ground floor the recess formed along one edge of a slab is bedded on the foundation beam, and the slabs placed above have the recess bedded on the upwardly-projecting part of the lower slab. On the first floor the construction is similar except that the first slab to be placed is supported by a steel angle. The horizontal and vertical edges of the slabs are not pointed. The ends of the slabs are fixed to the steel frame by metal clips attached to bolts cast in the slabs.

The architects, who designed the school for the Ipswich Education Committee, are Messrs. Johns & Slater, F./A.R.I.B.A. The general contractors are Messrs. V. A. Marriot, Ltd., and the precast concrete members were supplied by Messrs. Saunders (Ipswich), Ltd.

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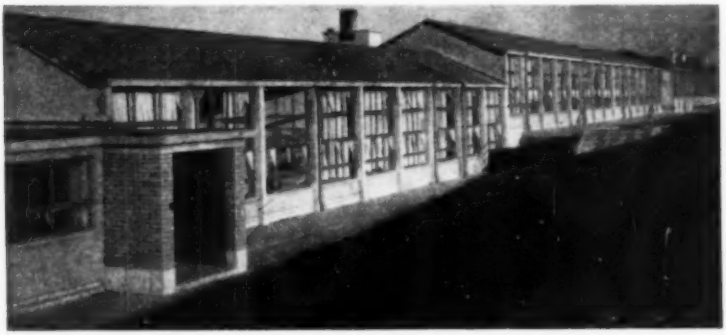

Fig. 1.—The West Classroom Wing.

THIS school (*Fig.* 1) is designed to accommodate 650 pupils and comprises sixteen classrooms, general-purpose room, arts and crafts rooms, offices, cloak-rooms, and lavatories. An assembly hall, with a stage and having a floor area of over 4000 sq. ft., is connected to a kitchen so that it can also serve as a dining room.

The construction (*Figs.* 3 and 4) is a combination of precast and in-situ concrete. With the exception of the offices, the buildings are all of one story and comprise reinforced concrete frames at 10-ft. centres, with walls and roofs of precast slabs. The standard span of the frames in the classrooms (*Fig.* 4) is 23 ft., in the general-purpose room and the kitchen 26 ft., and in the hall 40 ft. 6 in. The roofs are pitched, except those over the offices, kitchen annexes, lavatories, and main corridors which are flat.

The walls consist of precast concrete slabs between 3-in. by 3-in. columns cast in situ at 18-in. centres. The shuttering for the columns was formed by the angular-shaped vertical edges of the wall slabs. The horizontal units such as sole-units, window sills, wall beams, and head-

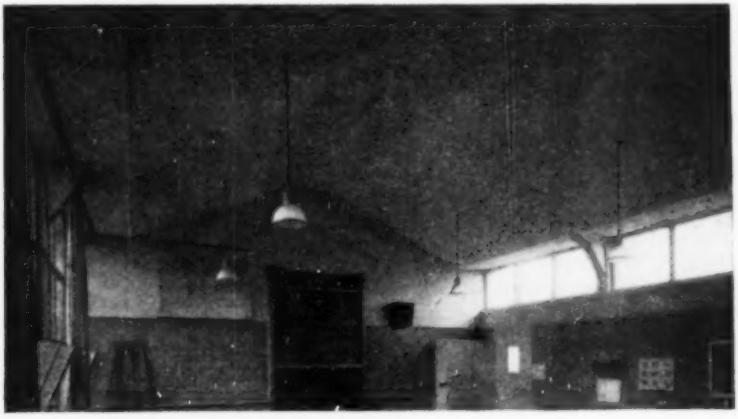

Fig. 2.—Interior of a Classroom.

plates are provided with rebates and stools which position and key the vertical components of the wall before concreting the in-situ columns.

The pitched roofs are constructed with inverted trough-shaped slabs spanning between the frames. These slabs are designed so that when they are in position and the sloping portions of the portal frames are concreted, an in-situ tee-beam is formed between the sloping portion of the frame and the precast roof slabs. Flat roofs are constructed with similar precast slabs which, in the case of the main corridors, span from wall to wall.

Rainwater gutters of precast concrete are laid on the top of the wall and are held in place by the roof slabs. The roof slabs and gutters are covered with three-ply bituminous felt having a green finish.

Except for the beams of the frames, the in-situ work generally requires no shuttering as the required shapes are formed by the precast slabs. The in-situ columns

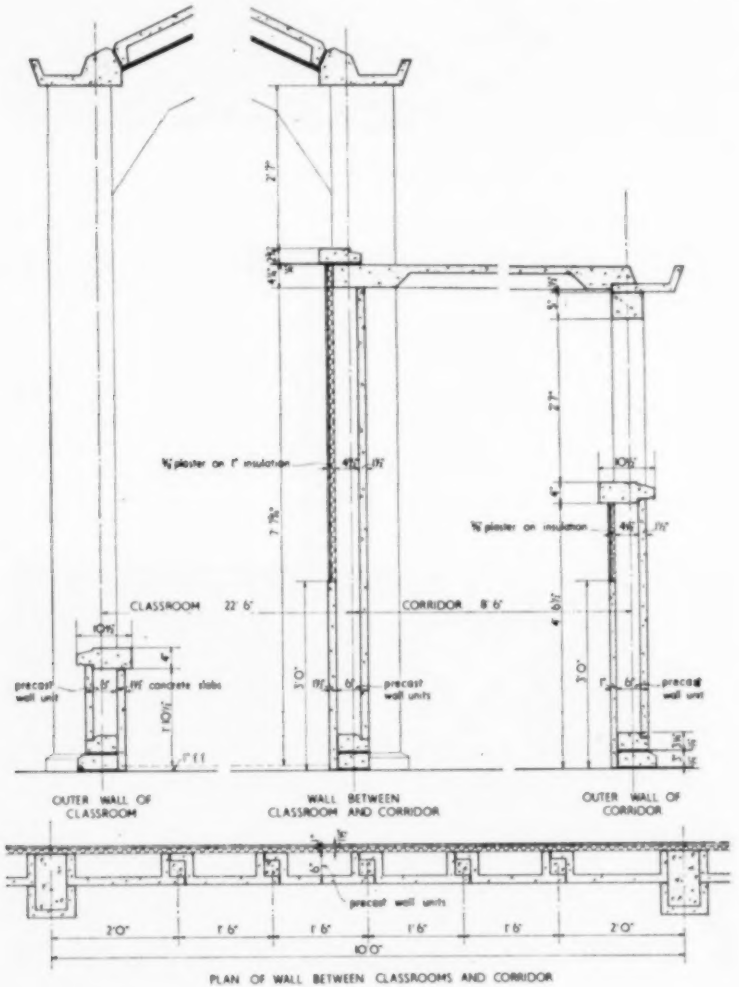

Fig. 3.—Details of the Construction.

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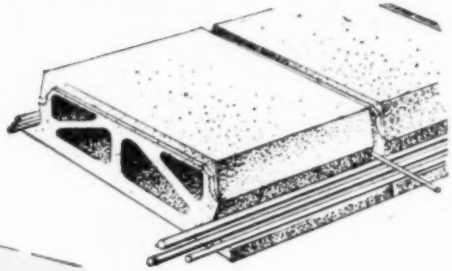

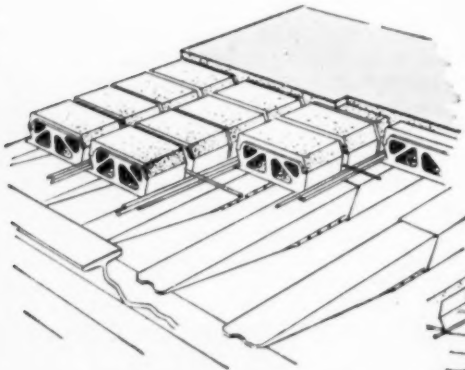

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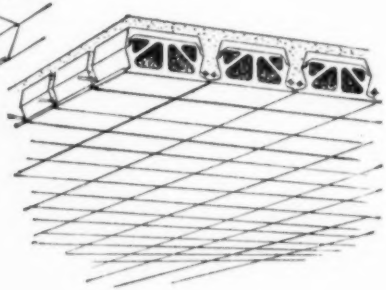

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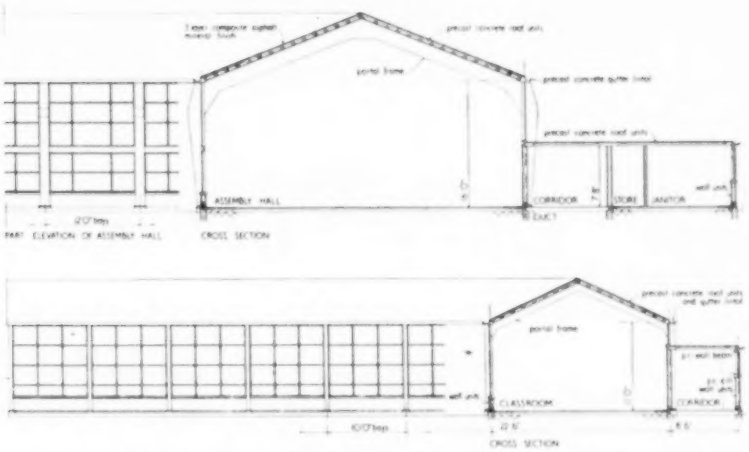

Fig. 4.—Sections and Elevations of the Classroom Wings and Assembly Hall.

tie the slabs to the foundations and floors and bond them to one another. The in-situ concrete in the inverted trough section at the ends of the floor slabs ensures a monolithic connection with the walls and beams and ties the slabs together.

The ground floor consists of 6 in. of concrete covered with 10-lb. bituminous sheeting on which is laid a 2½-in. concrete screed finished with 1 in. of plastic bituminous flooring. The 6-in. concrete sub-floor acts as a footing for the walls and partitions. Separate foundations are provided for the frames. Suspended floors of hollow precast slabs are laid in the principal corridors, the space below being used as a service duct.

The interior surfaces of the walls, up to dado height, are finished with precast slabs 1½ in. thick with a smooth finish; above this level they are lined with wood-wool slabs finished with plaster. All exterior surfaces are roughcast. The ceilings, which in the classrooms are finished just below the level of the undersides of the frames so as to give an unbroken surface, consist of insulating sheets, ½ in. thick, carried on metal tees suspended from copper straps passed through the joints between the roof slabs (*Fig. 2*). The cost, including the janitor's house and playgrounds, but exclusive of furnishings, will be about £100,000.

The architects are Messrs. J. A. O. Allan, Ross & Allan. The patentees of the system of construction, known as Precast Monolithic Construction, are Mr. Walter C. Andrews, O.B.E., M.I.C.E., and Mr. Edgar Hoenig, L.R.I.B.A.; this system used for the whole of the school. The contractors, who also made the precast units, are Messrs. W. J. Anderson, Ltd.

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THE two principal railway stations in Brussels have recently been connected by six lines of railway of which 1¼ miles is in a tunnel built by the cut-and-cover method. The tunnel follows the contours of the eastern slope of the valley of the river Senne and passes close to several historical buildings. The geological formation of the ground in which the tunnel was built consists, in the main, of a fine yellow-grey sand, saturated with water and containing widely-distributed patches of clay.

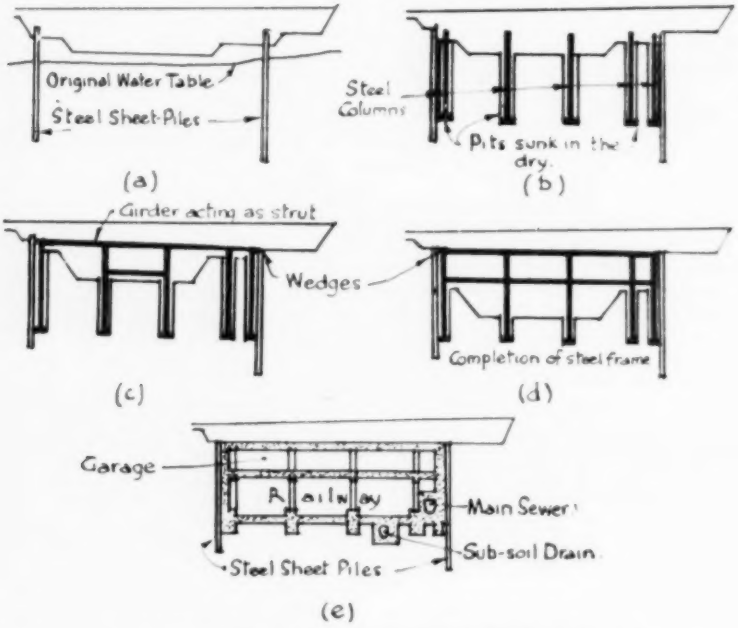

Fig. 1.—Stages in the Construction of the Tunnel.

Stages in the construction of the tunnel are shown in *Figs.* 1(a) to (e). The first operation was to drive steel sheet-piles, in some parts 90 ft. long, to form continuous curtains along each side of the projected trench and a well-point dewatering system was then installed within the area enclosed by the sheet-piles. This comprised three rows of pumping-shafts fitted with filters and penetrating below the future bottom of the trench. By this means the water-table was lowered sufficiently to enable all the work to be carried out in the dry. It was found that the sand would stand vertically when dry although its angle of repose when wet was not more than 5 deg. In the tunnel there are three pairs of tracks separated by rows of columns, and, separated from the tracks, a passage on the east side containing a main sewer. Frames of structural steel support the roof of the tunnel. The members of these frames were placed in position as the excavation proceeded and were arranged as walings and struts for the steel sheet-piling. In the early stages of the excavation steel columns were placed in shafts excavated in the sand and at the bottom of which a pad of concrete had been deposited. The walls of the shafts stood firm without linings as the sand had been drained of water.

On completion of the excavation a reinforced concrete floor was constructed and all the steel members were encased in concrete. The roof of the tunnel

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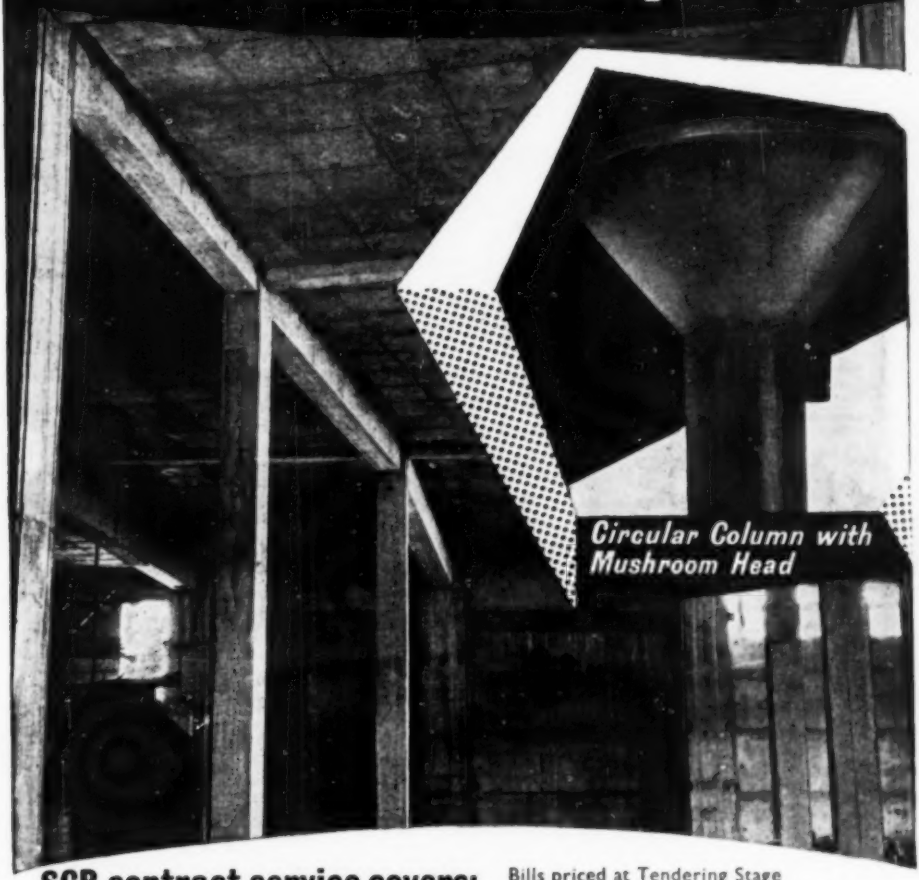

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(which is also the floor of a public garage) and the roof of the garage comprise broad-flanged steel joists encased in concrete, the compressive strength of which was taken into account.

A system of sub-soil drainage was incorporated along and under the eastern side of the tunnel to prevent the water-table rising above the underside of the foundations and access is possible to all parts of the system to enable the filtering media to be renewed and repairs to be carried out.

The quantities of some of the materials used in the works include 25,000 piles, 330,000 cu. yd. of concrete, and 54,000 tons of structural steel and reinforcement bars.

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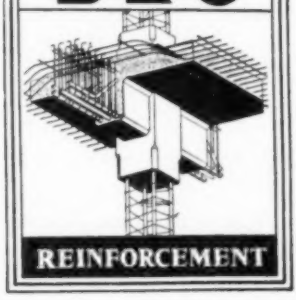

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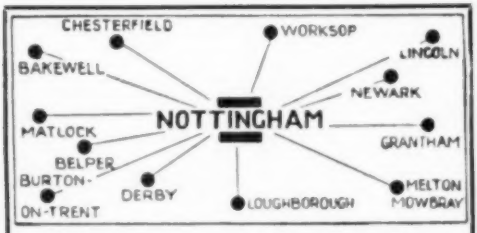

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(*Continued from page lxi.*)

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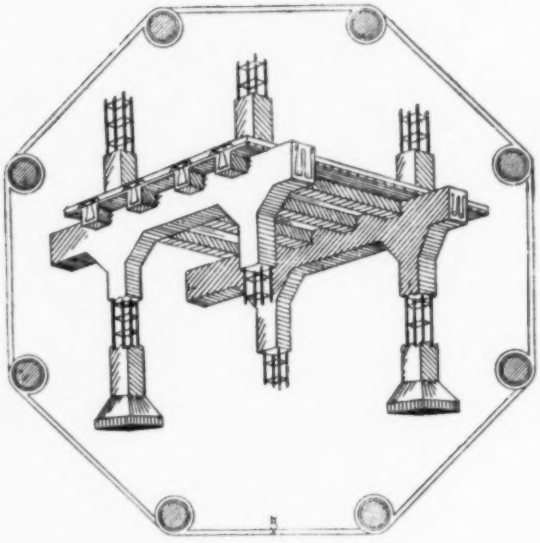

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